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TABLE OF CONTENTS

Vol. 22 March, 1939 No. 3

THE JOURNAL

Fundamentals of Color in Porcelain Enamels 65
By A. I. Andrews and C. H. Zwermann

Equations and Quadrant Charts for Determining Heat Balances of Kilns Using Solid or Liquid Fuels 72
By K. G. Skinner

Spalling of Silica Brick during Heating and Cooling of Furnaces 83
By J. M. McKinley and S. M. Phelps

Effect of Sodium Aluminate on the Thermal Expansion of Refractory Clays 88
By W. R. Morgan

Zinc-Vapor Glazing of Clays: I, Effect of Variable Iron Oxide and Alkalis in Clays on Zinc-Vapor Glaze Colors 91
By C. M. Lampman and H. G. Schurecht

Cone Fusion Study of Mixtures of Zirconium Silicate, Silica, and Alumina 95
By R. F. Rea

CERAMIC ABSTRACTS

18—3

Abrasives 65
Art and Archeology 66
Cements 68
Enamel 69
Glass 70
Structural Clay Products 74
Refractories 75
Terra Cotta 78
Whiteware 79
Equipment and Apparatus 79
Kilns, Furnaces, Fuels, and Combustion 82
Geology 83
Chemistry and Physics 86
General 88

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FUNDAMENTALS OF COLOR IN PORCELAIN ENAMELS*

By Andrew I. Andrews and Carl H. Zwermann

Abstract

Several different colored stains were prepared and added separately to a transparent enamel. The effect of fineness of the enamel, thickness of application, and various heat treatments on the colors obtained with application on both white and black undercoats were studied by analyzing the resulting colors with a K. & E. spectrophotometer. The percentage of reflectance for each wave-length in the visible spectrum was plotted. Microscopic and X-ray examinations were also made in order to study the factors producing the color changes noted.

I. Introduction

Colors, while pleasing to the public, offer many problems to the enameler. Hues and shades obtained from any one metallic coloring oxide or calcine vary tremendously, depending upon the composition of the enamel in which it is used, the fineness of the enamel, and the firing treatment. The usual procedure in the preparation of colored enamels consists of adding to a clear frit the coloring agent as a mill addition, the coloring agent being a calcine of a number of suitable compounds, usually metallic oxides.

The purpose of this work was to make a general study of various common coloring agents, prepared from materials of known composition, in sheet-iron cover enamels and especially to compare the color-reflectance curves of the colored enamels as measured on a spectrophotometer. This instrument measures the percentage of reflectance of the sample for each wave-length in the visible spectrum as compared with a standard, such as magnesium carbonate. Differences in hue and shade can be detected with the eye, but they can not be measured directly. Curves, however, may be plotted from spectrophotometer readings and colors may be compared directly. Colors with identical curves will appear the same in all kinds of light; colors that match by eye in daylight and do not have like spectrophotometric curves may not match in artificial light.

II. Review of the Literature

Harrison and Hartshorn[1] report that colors are usually added to enamels as part of the mill batch except in unusual cases, such as black or dark blue in which a part of the color is introduced in the frit batch. Their stains were ground, thoroughly washed, and added separately to enamels of varied compositions.

Baldwin[2] varied enamel compositions and noted the color stability at various temperatures. He also made frits in which the Na_2O to B_2O_3 ratio and the lime content were varied. He thought that the color variation might be due to a variation of the opacity of the frit, but from further tests he concluded that (1) better and brighter colors result by using less clay in the mill batch, (2) the color oxides are not always the controlling factor in producing the desired result, and (3) the composition of the frit used is of equal or greater importance than the color oxide.

An abstract[3] of an article from *Glashütte* states that pure cobalt oxide should not be used as such because, upon calcining, it absorbs oxygen and gives it up during enamel fusion. Cobalt should be added to the mill as an aluminate compound because the combining of cobalt oxide with alumina yields a pigment which does not give up oxygen and which produces a stable color. Chromic oxide can be added to the mill as such to produce a stable tone of pure green, or when melted with KNO_3 batches, it produces yellow-green.

Wenning[4] discusses the cause and control of color variations in cast-iron and sheet-iron enamels. He states that (1) any change or variation in color may be attributed chiefly to the heat reaction between the various chemicals which compose the color and the chemicals which compose the enamels, (2) variations in the composition of the enamel cause color variations even with the same coloring oxide, (3) opacifiers used in conjunction with stains produce pastel shades, and different opacifiers produce different effects, (4) grinding affects the color, and (5) overgrinding usually causes the color to become lighter.

R. Hainbach[5] gives compositions for a number of colors with factors affecting each.

Mellor[6] gives a comprehensive review on cobalt colors.

Stull and Baldwin[7] obtained a lilac stain by calcining cobalt with magnesia.

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* Presented at the Fortieth Annual Meeting, American Ceramic Society, New Orleans, La., March 30, 1938 (Enamel Division). Received March 30, 1938.

This paper has been prepared from a thesis written by the junior author to satisfy in part the requirements for the M.S. degree at the University of Illinois and is being published with the permission of the Dean of the Graduate School, University of Illinois, Urbana, Ill.

[1] W. N. Harrison and T. D. Hartshorn, "Preliminary Study of Ceramic Colors and Their Use in Vitreous Enamels," *Jour. Amer. Ceram. Soc.*, **10** [10] 747–60 (1927).

[2] W. J. Baldwin, "Color Stability in Enamels," *ibid.*, **18** [10] 321–22 (1935).

[3] "Reasons for Changes in Color in Cast- and Sheet-Iron Enamels," *Glashütte*, **63** [34] 571–74 (1933); *Ceram. Abs.*, **13** [4] 80 (1934).

[4] W. F. Wenning, "Cause and Control of Color Variation in Cast-Iron and Sheet-Iron Enamels," *Jour. Amer. Ceram. Soc.*, **12** [7] 491–93 (1929).

[5] R. Hainbach, Pottery Decorating, p. 105. Translated from the German by Scott, Greenwood, & Son, London, 1924.

[6] J. W. Mellor, "Cobalt and Nickel Colours," *Trans. Ceram. Soc.* [England], **36** [1] 1–9 (1937); *Ceram. Abs.*, **16** [9] 287 (1937).

[7] R. T. Stull and G. H. Baldwin, "Cobalt Colors Other Than Blue," *Trans. Amer. Ceram. Soc.*, **14**, 764–77 (1912).

Compositions suitable for colored enamel frits are covered by Andrews.[8]

Gaydon[9] has made color reflection and absorption measurements with the use of a neutral tint wedge on colored glazes containing chromium in the study of the chemical nature of the coloring agent. Because

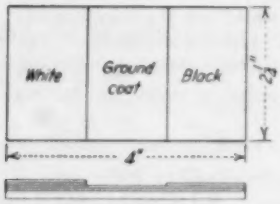

FIG. 1.

qualitative measurements are apt to be misleading, he made quantitative measurements. He states that the absorption curves for chrome-tin crimson, chrome-tin pink, and coral red are quite smooth and seem more like colors produced by particle size, and the curves for the chrome green, victoria green, chrome yellow, and chrome-brown tints suggest vibrational structure of the spectrum of a definite chemical molecule.

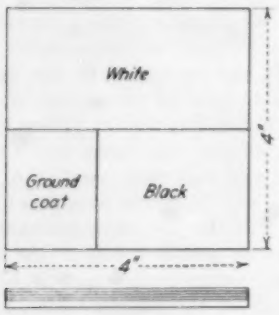

FIG. 2.

Shaw,[10] using a Hardy spectrophotometer, measured the colors formed by additions of single elements to a simple lead-silica glaze. The colors were then specified in the trichromatic system in terms of the three hypothetical primary colors, red, green, and violet, and in the monochromatic system in terms of hue, saturation, and brilliance. He further derived empirical relationships between the concentration of the chromatic elements and the three attributes of color.

Weyl[11] has made use of the absorption spectra of various glasses in studying ionic colors and discusses such factors as solvation of the coloring ions, dissociation and association equilibria, and the oxidation-reduction equilibrium.

III. Experimental Work

(1) Composition and Preparation of Colors

The compositions used for the stains are listed in Table I.

TABLE I

COMPOSITION OF RAW COLOR STAINS

Blue	(%)	Brown	(%)
Co_3O_4	20	Cr_2O_3	14
ZnO	20	Fe_2O_3	15
Al_2O_3	60	ZnO	59
Calcined 2350°F		Al_2O_3	12
		Calcined 2350°F	

Blue		Yellow	
Co_3O_4	20	Sb_2O_3	30
$MgCO_3$	80	Pb_3O_4	40
Calcined 2250°F		Al_2O_3	12
		SnO_2	18
		Calcined 2350°F	

Red		Yellow	
Se	20	V_2O_5 (90–95%)	10
CdS	72	ZrO_2	68
CdO	8	Pb_3O_4	22
		Calcined 2200°F	

Green	(%)
Cr_2O_3	39
$CaCO_3$	22
CaF_2	17
SiO_2	22
Calcined 2350°F	

Each batch was weighed, ground wet, dried, screened through a No. 60 sieve, and then calcined. The stains (except the selenium red) were calcined in a gas-fired pot furnace, allowing each stain four hours to reach the temperatures specified in Table I. The red was placed in a gas-fired frit furnace, previously heated to 1500°F, and was allowed to remain at this temperature until violent fuming took place. It was then removed, stirred, and again placed in the furnace until fuming took place.

The stains were ground wet, thoroughly washed in hot water, screened through a No. 200 sieve, and dried.

(2) Preparation of Test Pieces

Test pieces of commercial sheet iron were used in sizes indicated in Figs. 1 and 2. The pieces were pickled and ground-coated. Each was covered partly with a black cover enamel and partly with a two-coat superopaque white cover enamel with a reflectance as shown in Fig 3; the ground coat was exposed on the remainder of the piece. The second batch of test pieces was made up in one size only, with only the black and white cover coats exposed (Fig. 4).

[8] A. I. Andrews, Enamels, p. 185. Twin City Printing Co., Champaign, Ill., 1935; *Ceram. Abs.*, **14** [7] 158 (1935).

[9] A. G. Gaydon, "Absorption-Reflection Spectra of Chrome Colours," *Trans. Ceram. Soc.* [England], **36** [2] 49–55 (1937); *Ceram. Abs.*, **16** [9] 287 (1937).

[10] D. T. H. Shaw, "Color Formation in Raw Lead Glazes," *Jour. Amer. Ceram. Soc.*, **15** [1] 37–58 (1932).

[11] Woldemar Weyl, "Chemistry of Colored Glass: I–III," *Glass Ind.*, **18** [3] 73–78; [4] 117–20; [5] 167–71 (1937); *Ceram. Abs.*, **16** [6] 170; [7] 201; [8] 239 (1937).

(3) Composition and Preparation of Enamel Frit

The frit batch (Table II) was mixed dry, screened through a No. 20 sieve, and smelted in a gas-fired surface-combustion furnace at 2000°F in 90 minutes. The frit was quenched in water and dried.

TABLE II
Frit composition

Feldspar	28
Borax	35
Quartz	21
Soda ash	7
Soda niter	4
Fluorspar	5

(4) Preparation of Colored Enamels and Their Application

Frit batches of 500 grams each were weighed; 5% clay, 3% color stain, and 40% water were added. The batches were milled to a fineness, indicated in Table III, using the Standard Method for Fineness.[12] The enamels were sprayed to a dry weight of 32 grams per

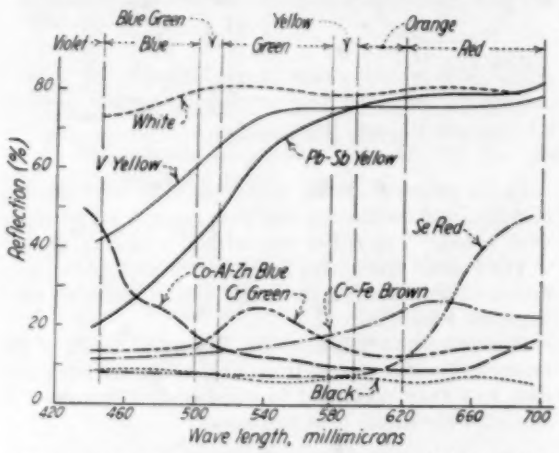

FIG. 3.—All colors: 3 coats over white, fired 1500°F for 3 min.

sq. ft. The pieces were then dried and the dry weights were checked. If the weight was not within 1/10 gram of the proper weight, the pieces were cleaned off and resprayed. Each enamel was fired in an electric

TABLE III
ENAMEL BATCHES AND MILLING DATA

	Frit	Color	Clay	Fineness on 200-mesh
Blue (Co-Zn-Al)	100	3	5	0.0
	100	3	5	0.5
	100	3	5	1.9
Red (Se)	100	3	5	13.6
	100	3	5	0.4
Green (Cr)	100	3	5	12.1
	100	3	5	0.4
Brown (Cr-Fe-Zn)	100	3	5	12.3
	100	3	5	1.2
Yellow (Pb-Sb)	100	3	5	11.9
	100	3	5	3.4
Yellow (V)	100	3	5	0.9
Blue (Co-Mg)	100	3	5	2.1
Mixture of red and green	100	3 (each)	5	1.1

[12] A. I. Andrews, Enamels, p. 329.

furnace over a range from immaturity to overfiring, approximately 1200° or 1300°F to 1700°F for 3 minutes; in some cases, a time-range of 1 1/2 to 4 1/2 minutes at 1500°F was used. Enough pieces were fired at each temperature to allow one and two more coats to be applied in a similar manner, thus giving a field with one, two, and three coats for each firing range (see Fig. 5).

(5) Measurements on Spectrophotometer

Each piece was so placed in the apparatus that readings could be taken over the black and over the white and in some cases over the ground coats (see Fig. 6). Readings were taken on the samples every

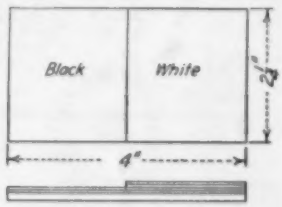

FIG. 4.

20 mμ (millimicrons), where the change in percentage of reflectance was gradual, and every 10 mμ, where the changes were abrupt over a range of 440 mμ to 690 mμ, corresponding to the visible range of the spectrum. Check readings were taken, and where discontinuities

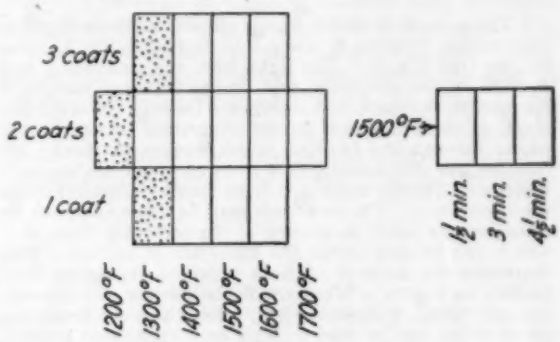

FIG. 5.

were noted additional readings were taken. The spectrophotometer was tested frequently for accuracy. A typical data sheet, such as was recorded for each sample, is given in Table IV.

(6) Plotting Results

Percentage reflectances at the different wave-lengths of light were plotted, and smooth curves were drawn for numerous combinations. Typical curves may be seen in Figs. 7 to 20.

(7) Microscopic Examinations

Several pieces were examined with dark- and light-field illuminations and a metallographic microscope with an approximate 600× magnification.

(8) X-Ray Data

A few powder patterns were taken to note crystallinity, if any, in some of the enamels. Exposures of 15 hours were made with a molybdenum K-alpha beam on powders, with the film placed 5 cm. from the sample.

TABLE IV

TYPICAL SPECTROPHOTOMETER READINGS*

Sample No. 6: Co-Al-Zn blue; fineness 1.9 g./200-mesh; 2 coats, fired 1500°F

Wave-length (mμ)	Reflectance (%) Over black	Over white
440	31	57
450	29	47
460	26	39
470	23	35
480	21.5	32
500	19	26
510	13.5	19
520	12	14
530	9	11
540	9	10
550	8	10
560	8	9
570	7	8
580	6.5	8
600	7	8
620	6.5	8
640	7.5	8.5
650	8	10
660	11	13.5
670	12.5	18.5
680	15	26
690	16	30
700	17	34

* The general principle of the Keuffel & Esser spectrophotometer (Keuffel & Esser Co., Hoboken, N. J.) is as follows (see Fig. 6): The light from the sources, *A* and *B*, falls on the sample, *a*, and on the standard sample of magnesium carbonate; it is reflected through the revolving disks, *b*, then dispersed by the dispersing prism, *p*, and passes through the bi-prism which divides the field. By rotating the dispersion prism through small angles, each wave-length of the visible spectrum may be viewed through the eyepiece, *f*. The two fields may be made to match by changing the angle of opening of the revolving disks at *b*, which can be done while the disks are in motion. This decreases the amount of light reflected from the magnesium carbonate. When the fields balance, the percentage reflectance of the wave-length for which the dispersion prism is set can be read directly on a calibrated scale, *s*, attached to the disk adjustment. The dispersion prism is then set for another wave-length and the fields are again balanced. The instrument is accurate within 1% except that at both ends of the visible spectrum it is difficult to make readings.

IV. Results

(1) Microscopic Examination

In the examination of the red stain in the enamel fired at the lower temperature, extremely small particles in a continuous band were seen as a layer between the frit particles. With increase in heat treatment, this layer dispersed, and the entire mass of enamel appeared red.

In the blue enamel, containing the Co-Al-Zn stain, particles of blue could be detected in the enamel between the clear frit particles. They diminished in size and finally disappeared with increasing heat treatment, forming a purplish-blue glass. Similarly, brown particles were noted in the brown enamel and green particles in the green enamel. These appeared to be in the intervening spaces between the frit particles, but in the case of the brown and green, the particles did not disappear with increasing heat treatment.

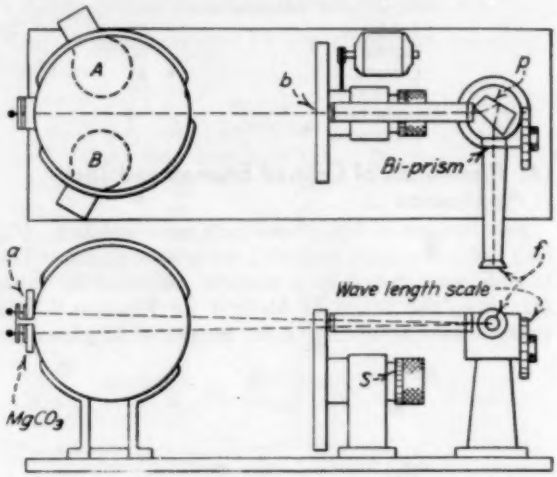

FIG. 6.—Top and side view of spectrophotometer.

In the yellow enamels, yellow particles were not discernible, and in the Co-Mg blue enamel no particles were noted. The entire enamel had a blue color.

The enamel containing both the red and green stains appeared as a mix of the two. Green particles were apparent among the red.

Numerous gas bubbles were also noted in all of the enamels; these appeared to occur between the frit particles, and they decreased in number and increased in size with increasing heat treatment.

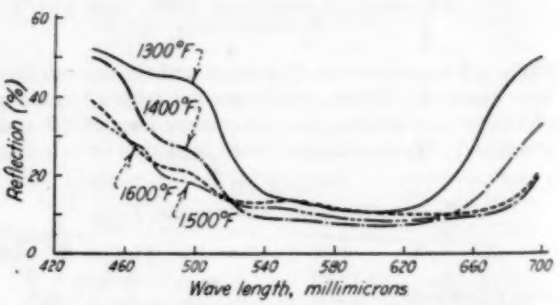

FIG. 7.—Temperature effect: blue enamel (Co-Al-Zn stain), 3 coats on black; fineness 0.5 g./200-mesh, fired for 3 min.

(2) X-Ray Examination

X-ray powder patterns of the Co-Al-Zn blue enamel, fired at the higher temperatures, showed only the diffuse ring typical of a glass, and no bands similar to those of the pattern for the stain itself were apparent.

A pattern of the red stain gave sharp lines that could also be identified as being identical with some faint lines obtained in the pattern of the red enamel.

V. Discussion

Enamels are not fired long enough to allow equilibrium to be reached, and it is only natural to expect variations in colored enamels with variations in heat treatment and also with grinding, because fineness

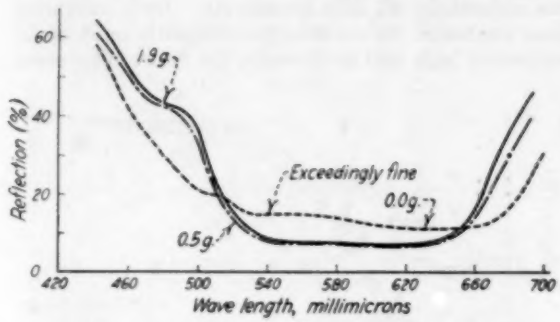

FIG. 8.—Grinding effect: blue enamel (Co-Al-Zn stain), 2 coats on white; fineness g./200-mesh, fired for 3 min. at 1400°F.

lowers the temperature at which fusion takes place. It is extremely difficult to heat irregular shapes uniformly; *e.g.*, in a single piece, variations in color occur, the amount depending considerably on the particular stain being used.

(1) Co-Al-Zn Stain

The Co-Al-Zn stain is itself a bright blue, probably due to cobalt aluminate and cobalt zincate. These give a greenish-blue color to the enamel at the lower heat treatments. The cobalt compounds dissolve in

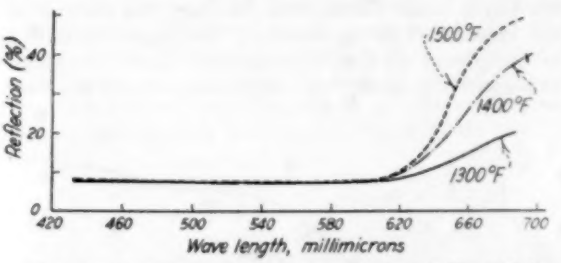

FIG. 9.—Temperature effect: red enamel (Se stain), 2 coats on white; fineness 0.4 g./200-mesh, fired for 3 min.

the enamel with increasing heat treatments and soon disappear in the frit, probably as cobalt silicate, giving it the purplish-blue color. These changes are apparent in the curves drawn from the spectrophotometer readings (see Figs. 7, 8, and 11).

(2) Co-Mg Stain

The Co-Mg stain is a light lavender. It dissolves readily in the enamel, and the purplish-blue color is probably due to cobalt silicate already being formed by the time the enamel glosses over. In the microscopic examination of this enamel, only colored glass was discernible; no colored particles were present. Additional heat treatment varied this color only slightly. Thus, if color stains that are soluble in the frit are to be used, it is much better to use the one that is more readily soluble to insure a uniform color over the entire firing range (see Fig. 18).

(3) Se Stain

The Se stain appears to be colloidal in the enamel. X-ray patterns of the enamel give lines corresponding to those in a pattern of the stain itself, indicating crystallinity; and because particles were not discern-

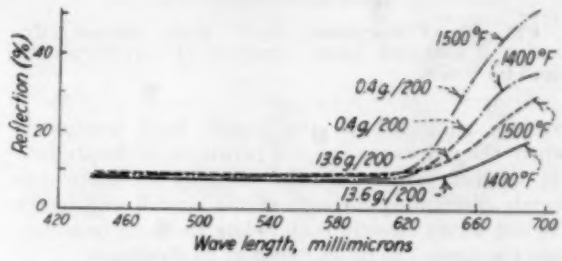

FIG. 10.—Grinding effect: red enamel (Se stain), 3 coats on black; fineness 0.4 g. and 13.6 g./200-mesh, fired for 3 min.

ible under the microscope in the case of the red enamels, which were subjected to the highest firing, they must be in the colloidal range. At the lower heat treatments, the particles of stain can be noted between the clear frit particles in a layer, but they have a definite red color when viewed under the microscope. The enamel itself appears brown to the naked eye. Additional heat treatment shows these red particles to be scattered throughout the frit and no clear frit is discernible; the enamel appears red to the naked eye. Spectrophotometer curves show an increase only in the red reflected as the change in the color due to higher

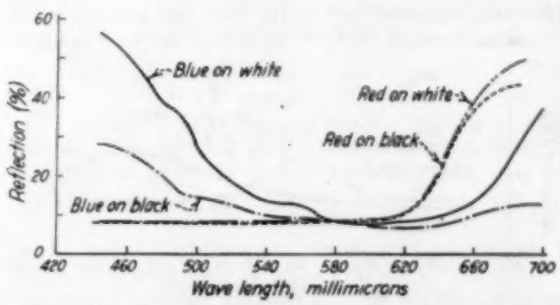

FIG. 11.—Covering comparison: one coat on black and white; red enamel (Se stain), 0.4 g./200-mesh; blue enamel (Co-Al-Zn stain), 0.5 g./200-mesh, fired for 3 min. at 1500°F.

heat treatments. This change in color is caused by the scattering of the particles in the enamel. These particles render the enamel opaque and absorb all wavelengths of light except the red (see Figs. 9, 10, and 11).

In the case of the low heat-treated enamels, the red particles are segregated between the larger frit parti-

cles. The transparent frit particles allow the light to penetrate into the enamel between these color layers. Most of the rays (except the red) are absorbed. The red is refracted and reflected within the enamel itself, and less of it is reflected back to the eye than in the

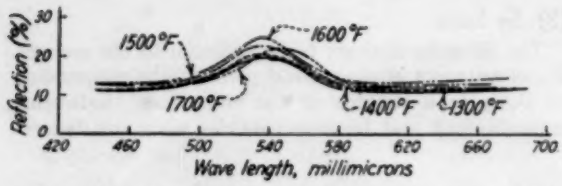

FIG. 12.—Temperature effect: green enamel (Cr stain), 2 coats on white; fineness 12.1 g./200-mesh, fired for 3 min.

enamels subjected to the higher heat treatments where the red waves can not penetrate so deeply into the enamel. Here the color particles are more uniformly distributed throughout the enamel and reflect the red waves directly back before they can penetrate into the enamel to be scattered in all directions.

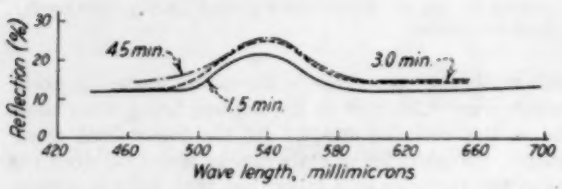

FIG. 13.—Firing time effect: green enamel (Cr stain), 2 coats on white; fineness 0.4 g./200-mesh, fired at 1500°F.

By grinding the enamel finer, these color particles become diffused throughout the enamel at lower heat treatments, and it is possible to get the red at lower temperatures. In the case of the red enamel used, blistering occurred both in the fine- and coarse-ground enamels at about 1600°F, probably due to volatiliza-

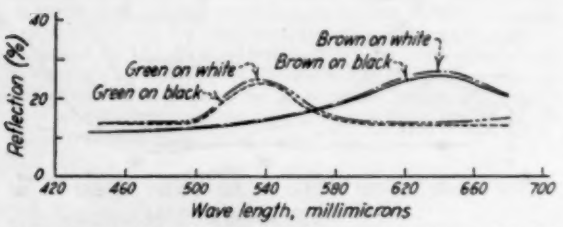

FIG. 14.—Covering comparison: 2 coats on black and white; green enamel (Cr stain), 0.4 g./200-mesh; brown enamel (Cr-Fe stain), 1.2 g./200-mesh, fired for 3 min. at 1500°F.

tion of the stain; the reflectance curves showed a considerably lower value in the red for the coarse enamel. Because the blistering occurred at a definite temperature in both cases and the reflectance increases in the red with the increase in the dispersion of the stain, it is absolutely necessary to control the grinding of the enamel to obtain a uniform color. The finer grinding is essential for the brightest reds in this type of enamel and stain.

(4) Cr-Green Stain

The Cr-green stain gave fairly uniform coloring in the enamel for all heat treatments. With increasing heat treatment, the color lightened slightly until, at the extremely high heat treatments, the entire color curve

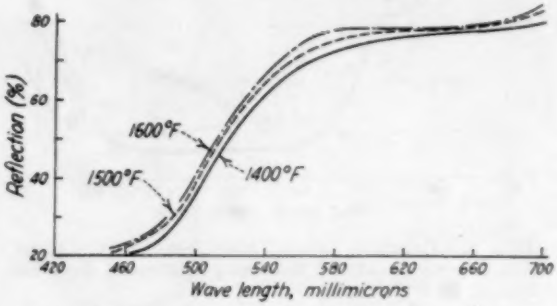

FIG. 15.—Temperature effect: yellow enamel (Pb-Sb stain), 2 coats on white; fineness 3.4 g./200-mesh, fired for 3 min.

darkened slightly and shifted toward the yellow. At the lower heat treatments, all sizes and shapes of green particles were apparent between the larger frit particles. There appeared to be no solution, inasmuch as the frit particles looked colorless and the stain appeared to be sharp-edged. At the extremely high heat treatments, there appeared to be an increase in the number of colored particles near and at the surface of the enamel, due possibly to the action of the gas bubbles or possibly to the relative density of the stain and the rest of the enamel. This accounts for the slight darkening of the enamel color with the extreme heat treatments. It is entirely possible that a slight dissolving of the stain

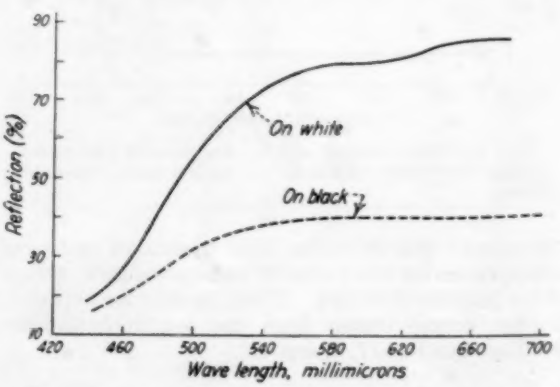

FIG. 16.—Covering comparison: 1 coat on black and white; yellow enamel (Pb-Sb stain), 3.4 g./200-mesh, fired at 1500°F for 3 min.

occurs, resulting in the change in the shade of the green. The increase in reflectance of the yellow indicates a reaction between Cr and Ca (see Figs. 12, 13, and 14).

(5) Fe-Cr Brown Stain

The Fe-Cr brown stain acted identically as the green in the enamel. The enamel first lightened with increasing heat treatments up to the extremely high heat treatments, at which time it darkened slightly.

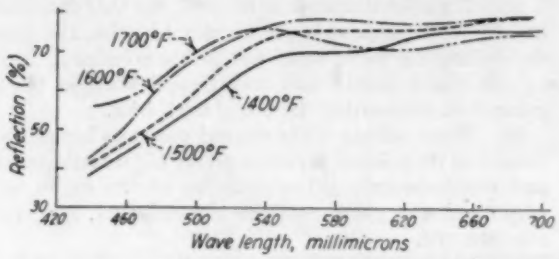

FIG. 17.—Temperature effect: yellow enamel (V stain), 2 coats on white; fineness 0.9 g./200-mesh, fired for 3 min.

All-size color particles were seen under the microscope, and no solution was noted even at the higher temperatures.

These two enamels, the green and the brown, under (4) and (5), indicate that for relatively insoluble stains the grinding time is not an all-important factor because uniform color is possible over a range of particle sizes. Grinding, however, should be kept constant in order to maintain constant maturing temperatures (see Figs. 14 and 19).

(6) Pb-Sb and V Yellow Enamels

The Pb-Sb yellow enamel showed no great difference in appearance to the eye over the entire range of heating. The spectrophotometer showed a slight lightening with increase in heat treatment. Under the microscope, no yellow particles were apparent, and it appears that the stain passes into solution even before the enamel glosses over. An enamel of this type, in which the color dissolves readily, is not improved from a color standpoint by fine grinding (see Figs. 15 and 16).

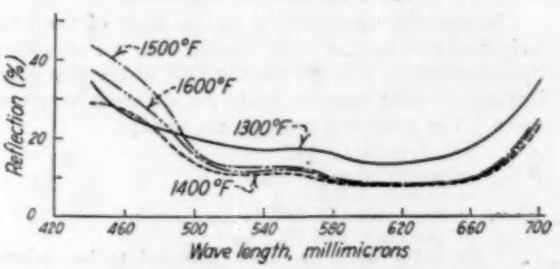

FIG. 18.—Temperature effect: blue enamel (Co-Mg stain), 2 coats on white; fineness 2.1 g./200-mesh, fired for 3 min.

The vanadium yellow enamel lost its color at extreme heat treatments, possibly due to solution. The stain made a nice color; but a change in composition of the stain is indicated (see Fig. 17).

The slight lightening of all the enamels with increasing heat treatment was due to the increase in the size and decrease in the number of the gas bubbles in the enamel and to their being scattered in the enamel.

(7) Red and Green Stains

The enamel containing 3% red and 3% green stains indicates promising possibilities in preparing colored enamels. Under the microscope, the enamel appeared as a mixture of the two separate colors. The green particles were much in evidence scattered among the red. At the lower temperatures, the red appeared in the layer between the frit particles along with larger green particles. At the higher heat treatments, the red seemed to be scattered throughout the enamel. The enamel appeared dark brown to the naked eye. The spectrophotometer gave a low reflectance curve over the entire spectrum except in the red where it increased slightly. Thus, the red stain absorbed all of the green waves and the green stain absorbed a portion of the red waves; otherwise the enamel would have been red instead of brown. If an additional percentage of green would absorb more red, a black would be obtained (see Fig. 20).

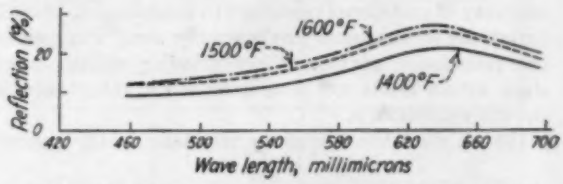

FIG. 19.—Temperature effect: brown enamel (Cr-Fe stain), 3 coats on black; fineness 1.2 g./200-mesh, fired for 3 min.

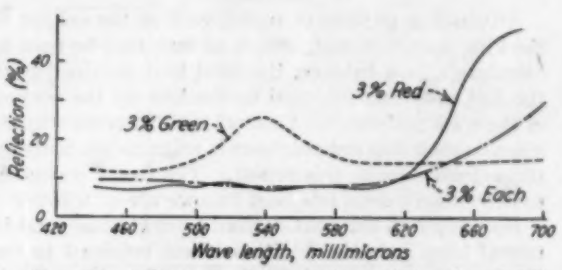

FIG. 20.—Effect of mixing stains: 3% red and 3% green; fineness 1.1 g./200-mesh; 2 coats fired at 1500°F for 3 min.

VI. Conclusions

(1) Spectrophotometric curves and microscopic or X-ray examinations of colored enamels, the latter to determine whether the color is due to solution or to particles (colloidal in size or larger) embedded in the enamel glass, are useful in the production and matching of colored enamels.

(2) With this information, it is easy to determine which stains can be blended and their resulting colors.

(3) The effects of temperature variations, firing time, and fineness on the color produced in the enamel are determined chiefly by the type of stain used. A study of the curves and the discussion for each color clearly shows these effects.

(*a*) Enamels that derive their color from suspended inert particles are preferable in most cases, *e.g.*, the green and brown stains. The spectrophotometric curves for the enamels using these stains show only small variations within wide limits of firing time, temperature, and fineness of the mill batch. The small changes noted on the curves are scarcely detectable to the naked eye. They appear to be due entirely to the changes in size and position of the gas bubbles present in the enamel. These will vary no matter what type of stain is used. In addition to being more stable, they have considerable opacity, thus reducing the necessity of additional opacifiers to a minimum. Small variations in thickness produce only small changes in the reflectance curves. Finer grinding of the inert stain within limits will also increase the reflectance of the colored enamels.

(*b*) A stain that dissolves gradually in the enamel will likely produce wide variations in color with changes in temperature, firing time, and fineness; *e.g.*, the Co-Al-Zn stain used in this work. A stain with this property may be used successfully, but uniform temperature, firing time, and fineness of stain and batch must be maintained carefully.

(*c*) If a soluble stain is to be used, one that dissolves rapidly in the enamel is preferable; likewise, the finer the milling the more rapid will be the solution. Such soluble stains should find useful application in black enamels in eliminating the use of dark frits.

(*d*) Finer milling of the enamel produces better dispersion of the colored particles, giving higher reflectance and simultaneously better stability of the colors, especially if the color particles are colloidal, *e.g.*, the selenium red.

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EQUATIONS AND QUADRANT CHARTS FOR DETERMINING HEAT BALANCES OF KILNS USING SOLID OR LIQUID FUELS*

By Kenneth G. Skinner

Abstract

Equations are derived for determining heat balances of kilns using solid and liquid fuels, and quadrant charts are given for graphic solutions. Charts and equations are also given for determining the weight of air supplied, theoretical weight of air required for combustion, percentage of excess air, volume of moist air, weight of refuse, percentage of hydrogen and oxygen from the moisture- and ash-free basis to the as-fired basis, and heat content of fuel oils of different specific gravities.

I. Introduction

Although a number of bases, such as the output of the kiln, weight of fuel, or unit of fuel, may be used to calculate a heat balance, the total heat obtained from the fuel plus that returned to the kiln by the cooling of the ware and cars (in a tunnel kiln) from their maximum to their exit temperatures is taken as the basis for the calculations in this report. The items necessary to determine a complete heat balance are as follows:

Heat input is the heat derived from the fuel, and in tunnel kilns it is the additional heat returned to the kiln by the ware and furniture cooling from their maximum to their exit temperatures. To determine the heat input for moving fire kilns, the heat from the cooling ware, furniture, and walls of the kiln should be added to that from the fuel.

Useful heat is the heat used for firing the ware plus that used for removing the mechanical water from the entering ware.

Heat losses are the sum of the heat lost out of the flue by the dry gases, water-vapor from the chemical water in the ware, moisture and hydrogen in the fuel, and vapor in the entering air; combustibles in the flue gas and in the refuse; hot ware and furniture leaving the kiln; and radiation and other losses, which are grouped as "unaccounted for" in this report.

II. Derivation of Equations

The equations are derived on the basis of the total weight of fuel fired, and the calculations are simplified by assuming an average specific heat of the flue gases instead of using specific heats for different temperatures. The following symbols are used:

A	=	ash in fuel (%).
B	=	weight of ashes (lb.).
API	=	degrees A.P.I.
B.t.u.	=	heat value of fuel (B.t.u. per lb.).
C	=	carbon in fuel (%).
C_a	=	combustible in ashes (assumed to be carbon) (%).
CO	=	carbon monoxide in flue gas (%).
CO_2	=	carbon dioxide in flue gas (%).
F	=	weight of fuel fired (lb.).
G	=	gallons.
H	=	hydrogen in fuel (as-fired basis) (%).
H_1	=	hydrogen in fuel (moisture- and ash-free basis) (lb.).
h	=	specific heat (moisture-free) of greenware from entering to maximum temp.
h_1	=	specific heat of fired ware from maximum to exit temp.

* Scheduled for presentation at the Forty-First Annual Meeting, American Ceramic Society, Chicago, Ill., April 16–22, 1939. Received August 12, 1938.

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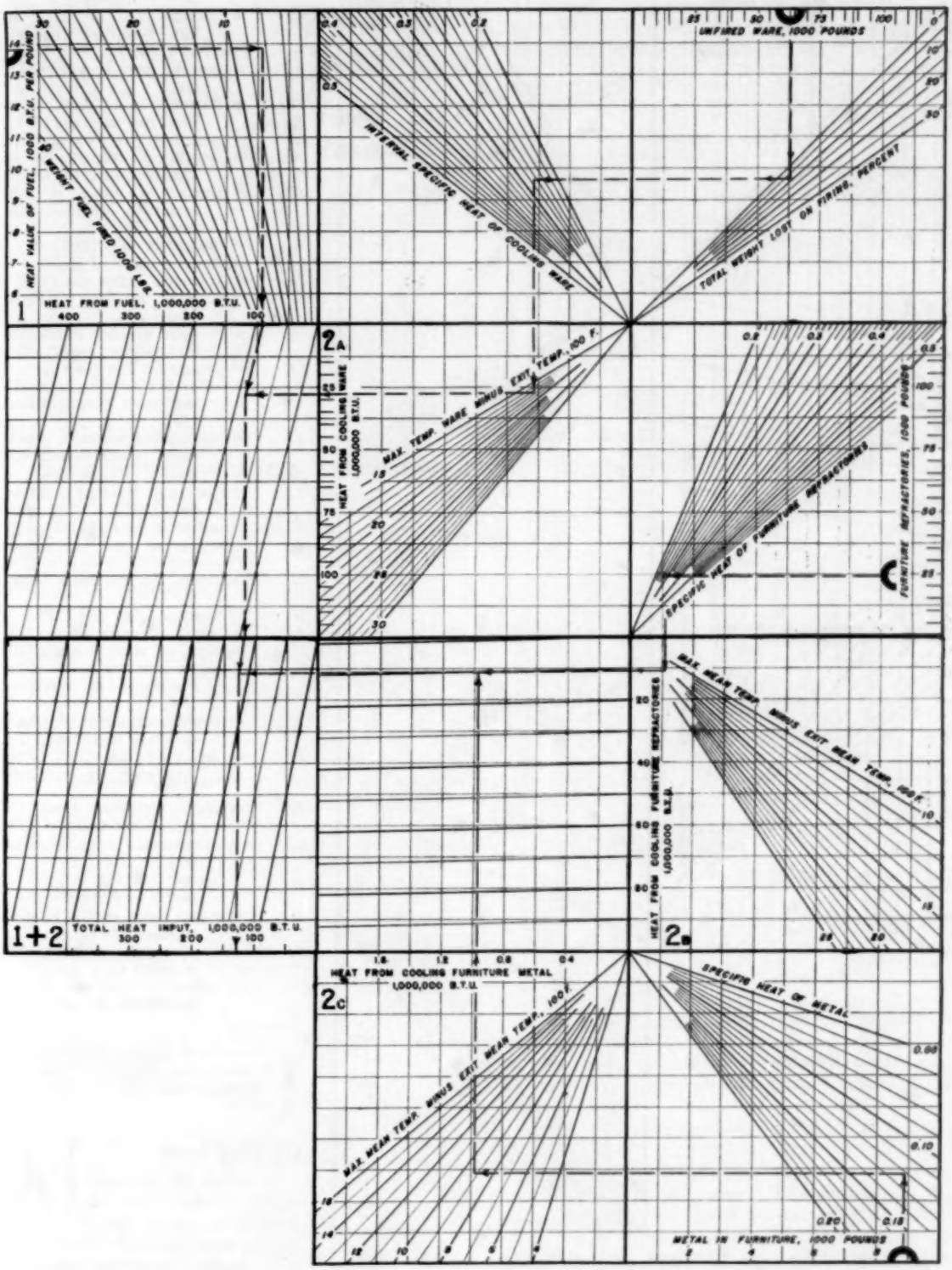
HEAT VALUE OF FUEL, 1000 B.T.U. PER POUND
WEIGHT FUEL FIRED 1000 LBS.
HEAT FROM FUEL, 1,000,000 B.T.U.
1
INTERVAL SPECIFIC HEAT OF COOLING WARE
UNFIRED WARE, 1000 POUNDS
TOTAL WEIGHT LOST ON FIRING, PERCENT
2A
MAX. TEMP. WARE MINUS EXIT TEMP., 100 F.
HEAT FROM COOLING WARE 1,000,000 B.T.U.
SPECIFIC HEAT OF FURNITURE REFRACTORIES
FURNITURE REFRACTORIES, 1000 POUNDS
2B
MAX. MEAN TEMP. MINUS EXIT MEAN TEMP., 100 F.
HEAT FROM COOLING FURNITURE REFRACTORIES 1,000,000 B.T.U.
1+2
TOTAL HEAT INPUT, 1,000,000 B.T.U.
HEAT FROM COOLING FURNITURE METAL 1,000,000 B.T.U.
2C
MAX. MEAN TEMP. MINUS EXIT MEAN TEMP., 100 F.
SPECIFIC HEAT OF METAL
METAL IN FURNITURE, 1000 POUNDS

FIG. 1.—Quadrant chart for determining the heat input. If no heat is exchanged, only the upper left quadrant would be used. If fuel oil is used, use Fig. 10 to determine the heat from the fuel. The large numbers refer to equation numbers, and the heavy dash line shows how to use the chart.

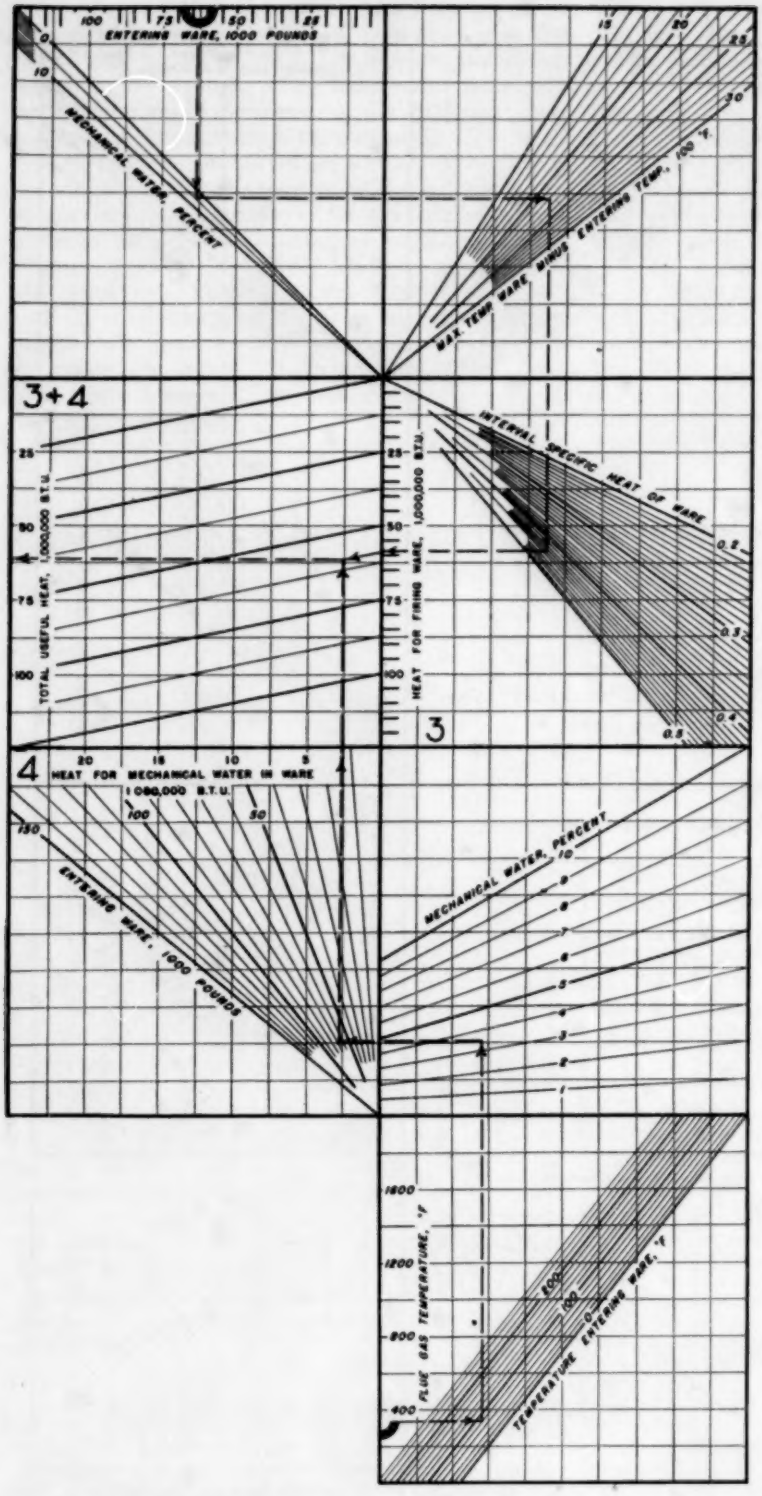

FIG. 2.—Quadrant chart for determining the useful heat, *i.e.*, the heat used for firing the ware and removing mechanical water. The heat lost by vapor from chemical water may be determined by substituting the temperature of outside air for the temperature of entering ware and chemical for mechanical water.

h_2 = specific heat of refractories in kiln furniture.
h_3 = specific heat of metal in kiln furniture (tunnel-kiln cars).
h_4 = specific heat in kiln walls, etc.
Hg = barometric or stack pressure (in. mercury).
M = weight of greenware* (lb.).
M_r = weight of refractories in kiln furniture (lb.).
M_m = weight of metal in kiln furniture (tunnel-kiln cars) (lb.).
M_k = weight of kiln (lb.).
m = moisture in fuel (%).
N_2 = nitrogen in flue gas (%).
O = oxygen in fuel (as-fired basis) (%).
O_1 = oxygen in fuel (moisture- and ash-free basis) (%).
O_2 = oxygen in flue gas (%).
p = total loss of weight in firing ware (green basis) (%).
q = mechanical water in greenware (green basis)(%).
R = weight of dry air (lb.).
s = chemical water (green basis) (%).
S = sulfur in fuel (%).
t_a = temp. of entering air or fuel (°F).
t_e = temp. of entering ware (°F).
t_f = temp. of flue gas (°F).
t_m = temp. of ware (max. °F).
t_L = temp. of ware (leaving °F).
t_1 = mean entering temp. of refractories in furniture (°F).
t_2 = mean max. temp. of refractories in furniture (°F).
t_3 = mean leaving temp. of refractories in furniture (°F).
t_4 = mean entering temp. of metal in furniture (°F).
t_5 = mean max. temp. of metal in furniture (°F).
t_6 = mean leaving temp. of metal in furniture (°F).
t_7 = mean temp. of kiln at start of firing (°F).
t_8 = mean temp. of kiln at finish of firing (°F).
w = vapor in entering air (lb. vapor/lb. dry air).

* Greenware is total weight of unfired ware, *i.e.*, weight of ware as loaded in the kiln including mechanical water.

(1) Heat Input

Although the actual heat input is that received from the fuel, the heat given up to the kiln system by the ware and cars (in a tunnel kiln) cooling from their maximum to their exit temperatures should be considered as part of the input; otherwise more than 100% heat

(heat from fuel basis) may be accounted for. Moving-fire kilns have about the same effect. Another justification for using this method is the fact that the heat used for firing the ware need not be grouped with the unaccounted-for heat, which might be 50 or 60% if these items were not considered. In Hoffman and similar kilns, efficiencies of more than 100% are obtained if no allowance is made for preheating the ware and for exchange of heat from hot sections of the kilns. The following equations are used for determining the heat input:

Heat from fuel (B.t.u.) = (B.t.u.) F (Fig. 1). (1)

Heat exchanged by cooling ware (B.t.u.) = $0.01\,(100 - p)(t_m - t_L)Mh_1$ (Fig. 1). (2a)

Heat exchanged by cooling furniture refractories (B.t.u.) = $(t_2 - t_3)M_r h_2$ (Fig. 1). (2b)

Heat exchanged by cooling furniture metal (B.t.u.) = $(t_3 - t_0)M_m h_3$ (Fig. 1). (2c)

Figure 1 is the quadrant chart for equations (1), (2a), (2b), and (2c). If the factors shown in equation (2) (sum of (2a), (2b), and (2c)) are used, the total heat input is shown in the lower left quadrant of the chart; if these factors are not considered, the heat input would be obtained in the upper left quadrant.

(2) Useful Heat

The total useful heat, as calculated in the following equations, is considered as that used for firing the ware plus that for evaporating the mechanical water. The equation recommended by the American Society of Mechanical Engineers[1] for determining the heat lost from moisture in the fuel is used to calculate the heat required to evaporate the mechanical water in the ware.

Heat for firing ware (B.t.u.) = $0.01(100 - q)(t_m - t_a)Mh$ (Fig. 2). (3)

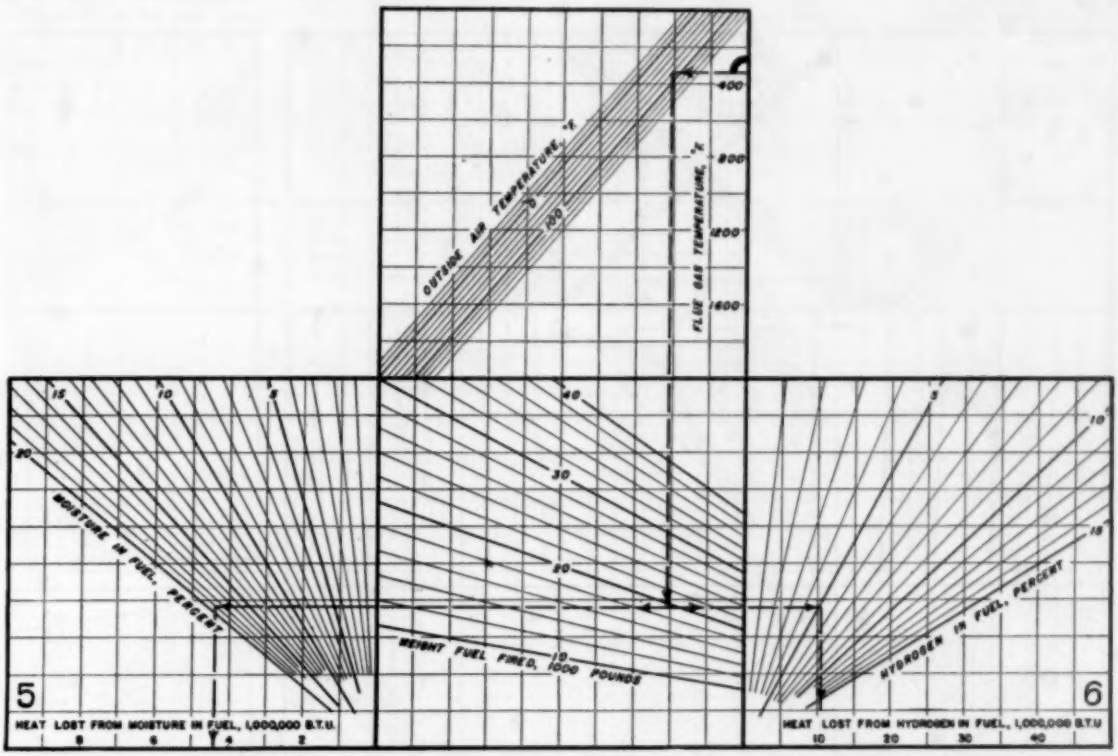
OUTSIDE AIR TEMPERATURE, °F
FLUE GAS TEMPERATURE, °F
MOISTURE IN FUEL, PERCENT
WEIGHT FUEL FIRED, 1000 POUNDS
HYDROGEN IN FUEL, PERCENT
5
6
HEAT LOST FROM MOISTURE IN FUEL, 1,000,000 B.T.U.
HEAT LOST FROM HYDROGEN IN FUEL, 1,000,000 B.T.U

FIG. 3.—Quadrant chart for determining the heat lost from moisture and hydrogen in the fuel.

Heat for evaporating mechanical water (B.t.u.) = $0.01(1091 + 0.455t_f - t_a)Mq$ (Fig. 2). (4)

Figure 2 is the quadrant chart for equations (3) and (4).

(3) Heat Losses

Because the various items considered as losses were previously outlined, only the equations for computing them will be given here. Radiation losses may be calculated, but they are considered "unaccounted for" in this report.

At times it is impossible to weigh the refuse; an equation (10a) is therefore given to calculate the theoretical weight when the percentage of ash in the fuel and refuse are known. The combustible in the refuse is assumed to be all other matter present than the ash. If moisture is present, the proximate analysis should be converted to the moisture-free basis

[1] James Ambrose Moyer, Power Plant Testing, p. 318, 4th ed., 2d impression. McGraw-Hill Book Co., Inc., New York, 1934.

(Fig. 9), and any volatile matter is considered to be carbon. The combustible in the refuse is assumed to be carbon with a heating value of 14,600 B.t.u. per pound.

Heat lost by vapor from chemical water (B.t.u.) $= 0.01(1091 + 0.455t_f - t_a)Ms$ (Fig. 2). (4a)

The weight of air supplied (equation (7a)), multiplied by the moisture in the entering air and the temperature difference, gives the heat lost by moisture in the incoming air. The factor, 0.375S, is the carbon equivalent of sulfur, which is the weight ratio of nitrogen in the products of combustion and is obtained from the nitrogen ratio for burning one pound of sulfur and one pound of carbon in air. These ratios are, respectively,

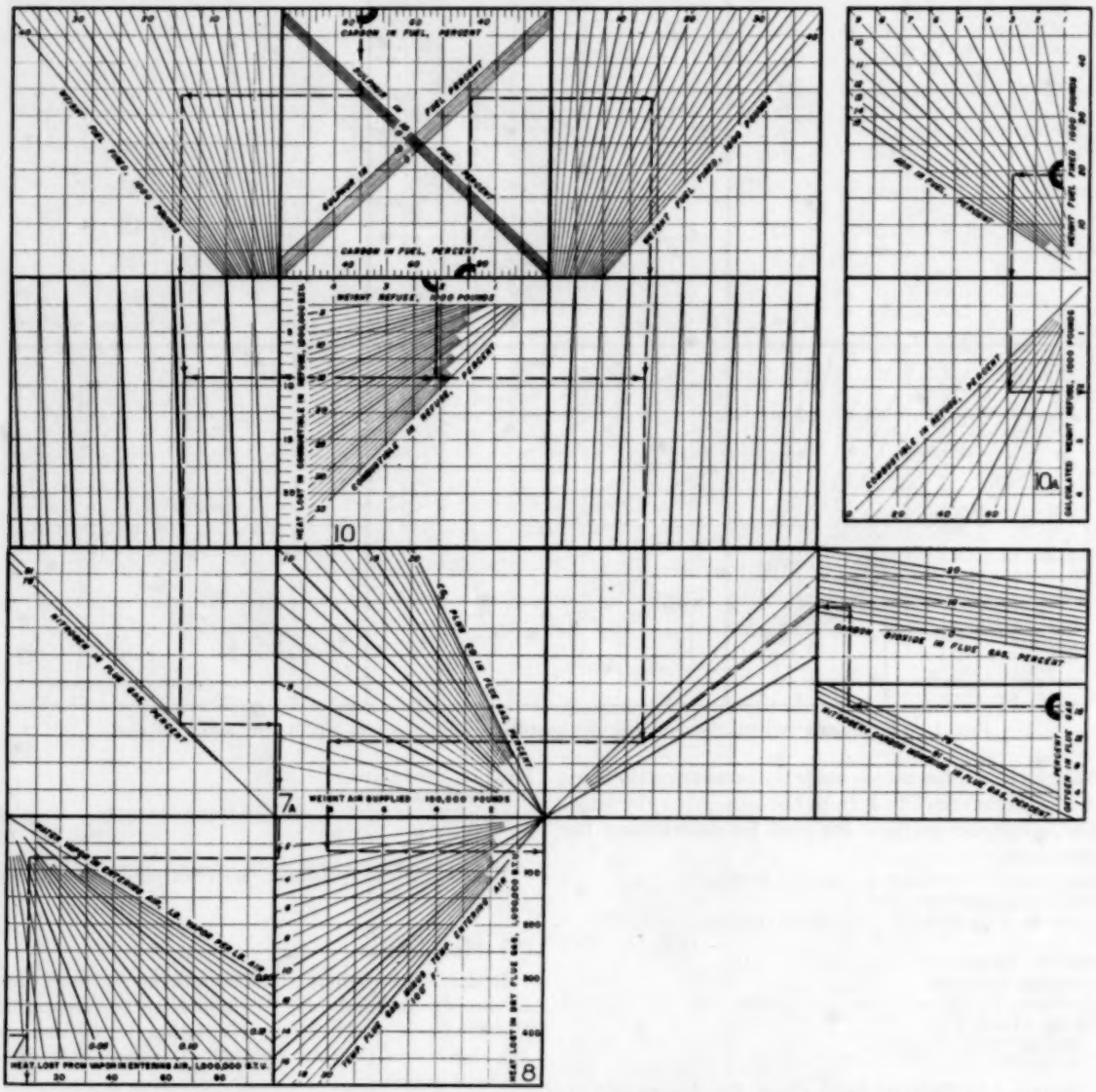

FIG. 4.—Quadrant chart for determining the heat lost from the dry flue gas, moisture in the entering air, and combustible in the refuse. The weight of air supplied may also be determined.

Heat lost by moisture in fuel (B.t.u.) $= 0.01(1091 + 0.455t_f - t_a)Fm$ (Fig. 3). (5)

Heat lost by hydrogen in fuel (B.t.u.) $= 0.09(1091 + 0.455t_f - t_a)FH$ (Fig. 3). (6)

Figure 3 is the quadrant chart for equations (5) and (6).

3.32 for sulfur to 8.85 for carbon or 0.375S.[2] The factor, 0.545S (equation (8)), is the carbon, equivalent[2] of sulfur dioxide and carbon dioxide for the ratios 2.00 and 3.667 of the products of combustion. Equations (7), (7a), and (8) can not be applied when gaseous

[2] Arthur D. Pratt, Principles of Combustion in the Steam Boiler Furnace, pp. 53–57. Babcock & Wilcox Co., New York, 1920.

fuels containing nitrogen are used because it is assumed that all of the nitrogen in the flue gas comes from the air and that additional large quantities would destroy the relationships from which the equations were derived. Slight errors are caused by the small quantity of nitrogen present in most solid and liquid fuels, but these are well within the limits of experimental error. Equation (8) must be corrected, if any illuminants are present in the flue gas.

Weight of air supplied for combustion (lb.) $= \frac{0.03036N_2}{CO_2 + CO}[(C + 0.375S)F - BC_a]$ (Fig. 4). (7*a*)

Heat lost in combustible in refuse (B.t.u.) $= \frac{\frac{146\ AF}{100}}{\frac{C_a}{}} - 1$ (Fig. 4). (10)

Heat lost in ware leaving kiln $= 0.01(t_L - t_a)(100 - p)Mh_2$ (Fig. 1). (11*a*)

Heat lost in refractories in kiln furniture (B.t.u.)
- heating up $= (t_2 - t_1)M_r h_2$ (Fig. 1). (11*b*)
- leaving kiln $= (t_3 - t_a)M_r h_2$ (Fig. 1). (11*c*)

Heat lost in metal in kiln furniture (B.t.u.)
- heating up $= (t_4 - t_4)M_m h_3$ (Fig. 1). (12)
- leaving kiln $= (t_4 - t_a)M_m h_3$ (Fig. 1). (12*a*)

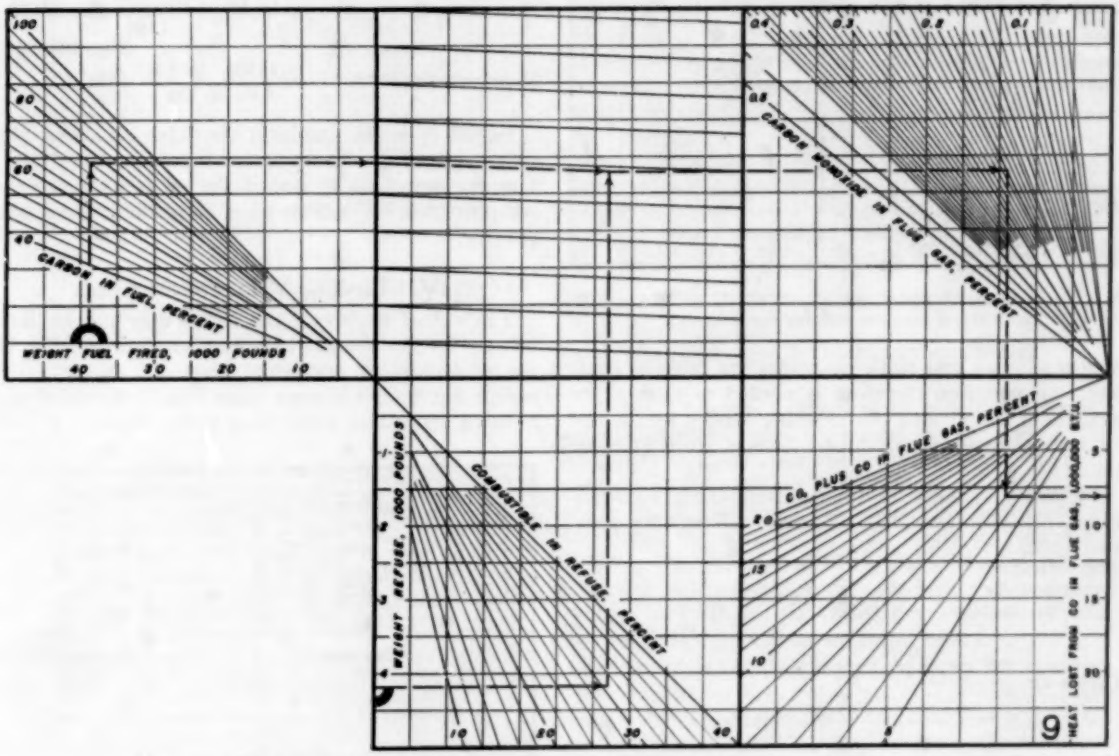
CARBON IN FUEL, PERCENT
WEIGHT FUEL FIRED, 1000 POUNDS
COMBUSTIBLE IN REFUSE, PERCENT
WEIGHT REFUSE, 1000 POUNDS
CO2 PLUS CO IN FLUE GAS, PERCENT
CARBON MONOXIDE IN FLUE GAS, PERCENT
HEAT LOST FROM CO IN FLUE GAS, 1,000,000 B.T.U.
9

FIG. 5.—Quadrant chart for determining heat lost from carbon monoxide in the flue gas.

Heat lost by moisture in entering air (B.t.u.) $= 0.47w(t_f - t_a)$(equation (7*a*)) (Fig. 4). (7)

Heat lost by dry flue gas (B.t.u.) $= 0.0008\left[\frac{11CO_2 + 8O_2 + 7(N_2 + CO)}{CO_2 + CO}\right][(C + 0.545S)F - BC_a](t_f - t_a)$ (Fig. 4). (8)

Heat lost by carbon monoxide in flue gas (B.t.u.) $= \frac{101.6(CO)(CF - BC_a)}{CO_2 + CO}$ (Fig. 5). (9)

Calculated weight of refuse (lb.) $= \frac{A\ F}{100 - C_a}$ (Fig. 4). (10*a*)

Heat lost (stored) in kiln (B.t.u.) $= (t_3 - t_7)M_3 h_4$ (Fig. 1). (13)

Heat lost by radiation and unaccounted for (B.t.u.) $=$ by difference (no fig.). (14)

Figure 4 is the quadrant chart for equations (7), (7*a*), (8), (10), and (10*a*) and Fig. 5 for equation (9). Equations (11), (12), and (13) may be solved graphically by using the proper quadrants in Fig. 1; for example, equation (12) could be solved by using the quadrants for equation (2*c*).

III. Miscellaneous Formulas

(1) Air Relationships

The actual weight of air supplied (equation (7*a*)) was given and may be compared with the theoretical

air required, as calculated from the chemical analysis of the fuel (equation (15)) and the excess air determined. Equation (16) gives a rapid method of determining the excess air by the use of an oxygen-nitrogen balance. This equation can not be used for gaseous fuels containing

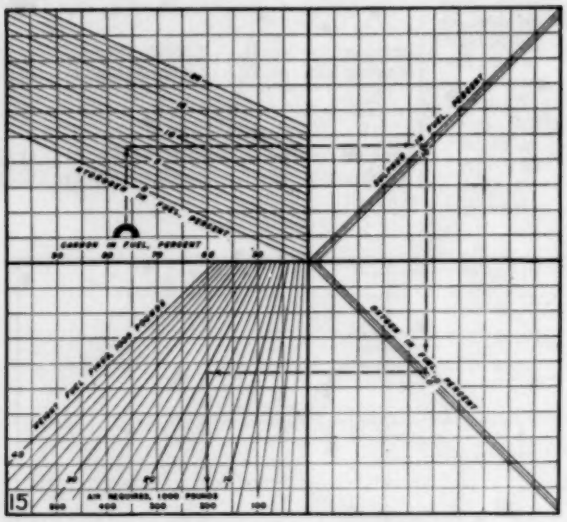

FIG. 6.—Quadrant chart for determining weight (theoretical) of air required for combustion.

nitrogen. Fan and stack capacities are given in cubic feet; an equation therefore is needed to change the weights of dry air and the moisture carried by the dry air into volume relationships. This is given in equation (17).

Figures 6, 7, and 8 are the quadrant charts for equations (15), (16), and (17). There is no chart for equation (16*a*).

$$\text{Theoretical air required for combustion (lb.)} = 0.0432(2.67C + 8H - O + S)F \quad \text{(Fig. 6).} \quad (15)$$

$$\text{Excess air (\%)} = \frac{(100)O_2}{0.263N_2 - O_2} \quad \text{(Fig. 7).} \quad (16)$$

$$\text{Excess air (\%)} = \frac{((7a) - (15))(100)}{(15)} \quad \text{(no. fig.).} \quad (16a)$$

$$\text{Volume of moist air (cu. ft.)} = \frac{0.754(1 + 1.605w)(460 + t)R}{\text{Hg}} \quad \text{(Fig. 8).} \quad (17)$$

(2) Conversion Formula for Fuels

(*A*) *Moisture- and Ash-Free Analysis:* Fuel analyses given on the moisture- and ash-free basis may be changed to the as-fired basis by means of the equation given by the American Society for Testing Materials Committee on Coal and Coke.[3] Figure 9 is the quadrant chart for equations (18*a*) and (18*b*).

$$\text{Hydrogen, as-fired basis, calculated from moisture- and ash-free basis (\%)} = [1 - 0.01(A + m)]H_1 + 0.111m \quad \text{(Fig. 9).} \quad (18a)$$

$$\text{Oxygen, as-fired basis, calculated from moisture- and ash-free basis (\%)} = [1 - 0.01(A + m)]O_1 + 0.889m \quad \text{(Fig. 9).} \quad (18b)$$

(*B*) *Fuel Oil:* Fuel oil is sold by the gallon, and the heat values are given either in B.t.u. per gallon or per pound, and because the weight per gallon will vary, a comparison of the total heat content may be necessary. Equations (19), (20), and (21) give the relationships of specific gravity (*API*), gallons, pounds, B.t.u. per pound, B.t.u. per gallon, and total heat content of fuel oil.

$$\text{Oil (lb.)} = \frac{1180G}{API + 131.5} \quad \text{(Fig. 10).} \quad (19)$$

$$\text{Heat value (B.t.u./lb.)} = \frac{(\text{B.t.u./gal.})(API + 131.5)}{1180} \quad \text{(Fig. 10).} \quad (20)$$

$$\text{Heat content (B.t.u.)} = \frac{1180G\ (\text{B.t.u.})}{API + 131.5} \quad \text{(Fig. 10).} \quad (21)$$

Figure 10 is the quadrant chart for equations (19), (20), and (21). The relationships are based on a temperature of 60°F, and if the oil is used at other temperatures, corrections must be made in the specific gravity.

IV. Limiting Values of the Charts

The values shown on the charts may not be satisfactory for certain products and conditions. By the use of factors or additional lines, all of the figures except Fig. 9 (and in some cases Figs. 4, 6, and 8) may be used for values other than those shown. If addi-

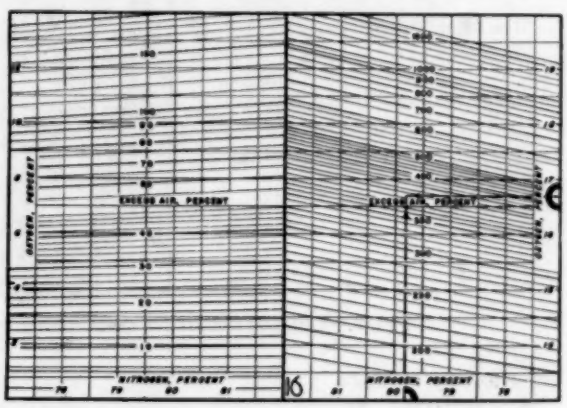

FIG. 7.—Quadrant chart for determining percentage of excess air, using an oxygen-nitrogen balance.

tional lines can not be drawn for values of CO, CO_2, N_2, and/or O_2 in Fig. 4, or if the carbon in the fuel is less than 40% in Figs. 4 and 6, these figures must be redrawn. In Fig. 8, a factor may be used either for the weight of air or the pressure, but if values other than those indicated for weight of vapor per pound of dry air or temperature are to be used, the figure must be redrawn.

If any of the weights (gallons in Fig. 10) for Figs. 1, 2, 3, 4, 5, and 10 are greater than those given, divide

[3] A.S.T.M. Standards on Coal and Coke, D271–33, p. 14 (Sept., 1936).

or multiply all of the weights by the same factor and then multiply or divide the answer by this factor. Draw additional lines for the other values shown on these figures. Do not use the upper left-hand quadrant

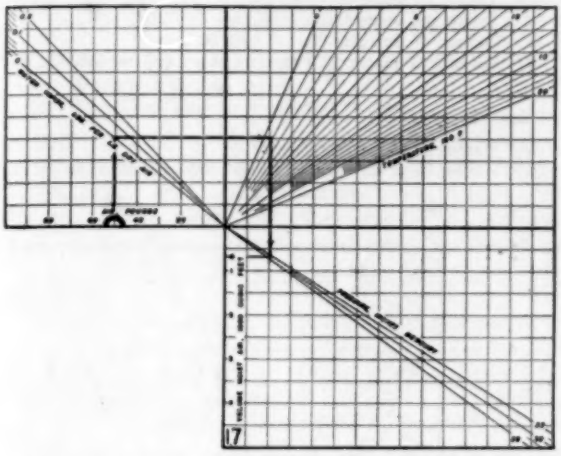

FIG. 8.—Quadrant chart for determining volume of moist air.

of Fig. 1 for determining the heat input of fuel oil unless the weight and heat value per pound are known (use Fig. 10). The following examples illustrate the use of factors.

Example

Given:

(*a*) Weight of greenware (M) = 19,050 lb.
(*b*) Weight of car refractories (M_r) = 7110 lb.
(*c*) Weight of car metal (M_m) = 2670 lb.
(*d*) Weight of coal fired (F) = 1937 lb.
(*e*) Temp. of outside air (t_a) = 79.2°F.
(*f*) Temp. of flue gas (t_f) = 340°F.
(*g*) Temp. of entering cars and ware (t_e, t_1, t_4) = 79.2°F.
(*h*) Temp. of ware (max. t_m) = 2275°F.
(*i*) Temp. of ware (leaving t_L) = 498°F.
(*j*) Temp. of car refractories (mean max. t_3) = 2196°F.
(*k*) Temp. of car refractories (mean exit t_3) = 498°F.
(*l*) Temp. of car metal (mean max. t_4) = 1160°F.
(*m*) Temp. of car metal (mean exit t_4) = 246°F.
(*n*) Ultimate analysis of fuel (%): 76.2 C, 5.2 H, 7.7 O, 1.5 N, 1.9 S, and 7.5 ash.
(*o*) Proximate analysis of fuel (%): 53.2 fixed carbon, 37.4 volatile, 7.5 ash, and 1.9 H_2O (m).
(*p*) Proximate analysis of refuse (%): 30.4 C and 69.6 ash.
(*q*) Heating value of fuel = 13,800 B.t.u. per lb.
(*r*) Flue-gas analysis (av. %): 3.3 CO_2, 16.7 O_2, 0.2 CO, and 79.8 N_2.
(*s*) Mechanical water in ware (q) = 3.5 (%) (green basis).
(*t*) Total weight lost on firing (p) = 9.05%.
(*u*) Specific heat of moisture-free unfired ware (h) = 0.43.
(*v*) Specific heat of fired ware (h_1, h_2) = 0.27.
(*w*) Specific heat of metal (h_3) = 0.12.
(*x*) Vapor in entering air (w) = 0.007 lb. per lb. dry air.
(*y*) Barometric pressure (Hg) = 30 in. mercury.

V. Explanation of Charts and Examples*

* Full-size black-line prints of the charts shown in this report may be obtained from the College of Mines, University of Washington, Seattle, Wash. Respective sizes and prices of the prints are as follows:

Fig. No.	Approximate size (in.)	Price each (cents
1	34 x 44	45
2	24 x 44	40
3	24 x 34	25
4	44 x 44	85
5	24 x 34	25
6	24 x 26	25
7	24 x 24	25
8	24 x 24	25
9	24 x 35	25
10	22 x 24	25

The full set will be furnished for $3.25.

Figure 1. Equations (1) and (2)

Given:

(*a*) Heat value of fuel (B.t.u. per lb.) = 13,800.
(*b*) Fuel fired (F) = 1937 lb.
(*c*) Weight of greenware (M) = 19,050 lb.
(*d*) Total weight lost on firing (p) = 9.05%.
(*e*) Specific heat of cooling ware and furniture refractories (h_1, h_2) = 0.27.
(*f*) Temp. of ware (max. t_m) = 2275°F.
(*g*) Temp. of ware and car refractories (leaving t_L, t_3) = 498°F.
(*h*) Weight of car refractories (M_r) = 7110 lb.
(*i*) Temperature of car refractories (max. t_3) = 2196°F.
(*j*) Weight of car metal (M_m) = 2670 lb.
(*k*) Temp. of car metal (max. t_4) = 1160°F.
(*l*) Temp. of car metal (exit) (t_4) = 246°F.

To determine:

(*a*) Heat from fuel.
(*b*) Heat exchanged by cooling ware and cars.

Method: A factor, a divisor of 0.3, is used to determine the heat inputs because the weight of ware fired is comparatively small and, for the scales used, more accurate results may be obtained if the values are closer to the center of the quadrants. All answers obtained from this chart must be multiplied by 0.3. There are four points of entry, but the chart will be explained for the solution of each item considered in the heat input. The answers given in the text are the corrected answers, *i.e.*, the indicated answers have been multiplied by 0.3.

Follow the heavy dash line in the upper left quadrant from the vertical line, representing 13,800 B.t.u., horizontally to the right to the radial line, representing the weight of fuel fired (1937 ÷ 0.3), and vertically downward to the heat from the fuel scale on the base line (26,700,000 B.t.u.).

The second point of entry is the upper right quadrant from the base line at 63,500 lb. Follow the heavy dash line vertically downward to the radial line representing the total weight lost on firing (9.05%); continue left to the diagonal line for the specific heat of the cooling ware (0.27), vertically downward to the diagonal line, representing the difference between the maximum and the exit temperatures of the ware (2275° − 498° = 1777°), and horizontally to the left to the scale of heat from cooling ware on the vertical line (8,350,000 B.t.u.).

Simple two-quadrant charts are used to determine the heat from the cars. The starting points are the right vertical scale, representing the weight of furniture refractories (23,700 lb.), and the lower left horizontal scale, representing the weight of furniture metal (8900 lb.).

The answers are obtained from the vertical scale, heat from cooling furniture refractories (3,250,000 B.t.u.), and from the horizontal scale, heat from cooling furniture metal (293,000 B.t.u.).

The total heat input is obtained from the chart by starting at the lower horizontal line of the upper left quadrant, representing the value of heat from the fuel (26,700,000 B.t.u.). Follow the heavy dash line diagonally to the left to the point at which it intersects the horizontal line projected from the value of heat from cooling furniture refractories (3,250,000 B.t.u.), vertically downward to the horizontal line dividing the two quadrants, diagonally downward to the left to the intersection of the horizontal line, representing the total heat from the cars, and then vertically downward to the total heat-input scale (38,600,000 B.t.u.).

The line representing the total heat from the cars is obtained as follows: Follow the heavy dash line diagonally to the left from the vertical line, representing heat from the refractories, to the point at which it intersects the vertical line projected from the scale for heat from furniture metal. The horizontal line extended to the left represents the sum of these two quantities.

Equations (11*a*), (11*b*), (11*c*), (12), (12*a*), and (13) may be solved by using this same chart and substituting the proper weights and temperatures. Solutions of these equations are not shown in the figure because the additional lines would be confusing.

Figure 2. Equations (3), (4), and (4a)

Given:

(*a*) Weight of green entering ware (M) = 19,050 lb.
(*b*) Mechanical water in entering ware (q) = 3.5%.
(*c*) Temp. of ware entering (t_e) = 79.2° F.
(*d*) Temp. of ware (max.) (t_m) = 2275°F.
(*e*) Temp. of flue gas (t_f) = 340°F.
(*f*) Chemical water in entering ware (s) = 5.55%.

To determine:

(*a*) Useful heat for firing ware.
(*b*) Useful heat for removing mechanical water in ware
(*c*) Total useful heat ($a + b$).
(*d*) Heat lost in vapor from chemical water in ware.

Method: A simple chart, composed of two three-quadrant charts and another quadrant for the addition of the values found for the two equations, is used. Two points of entry, the base line of the upper left quadrant, representing the weight of entering ware, and the vertical line, representing the flue-gas temperature in the lower left quadrant, are used. The total useful heat is given on the vertical scale of the left middle quadrant. A division factor of 0.3 is used for this chart.

The heat lost in vapor from chemical water in the ware is found by substituting the temperature of the outside air for the temperature of the ware (the same in this example) and the percentage of chemical water for the percentage of mechanical water.

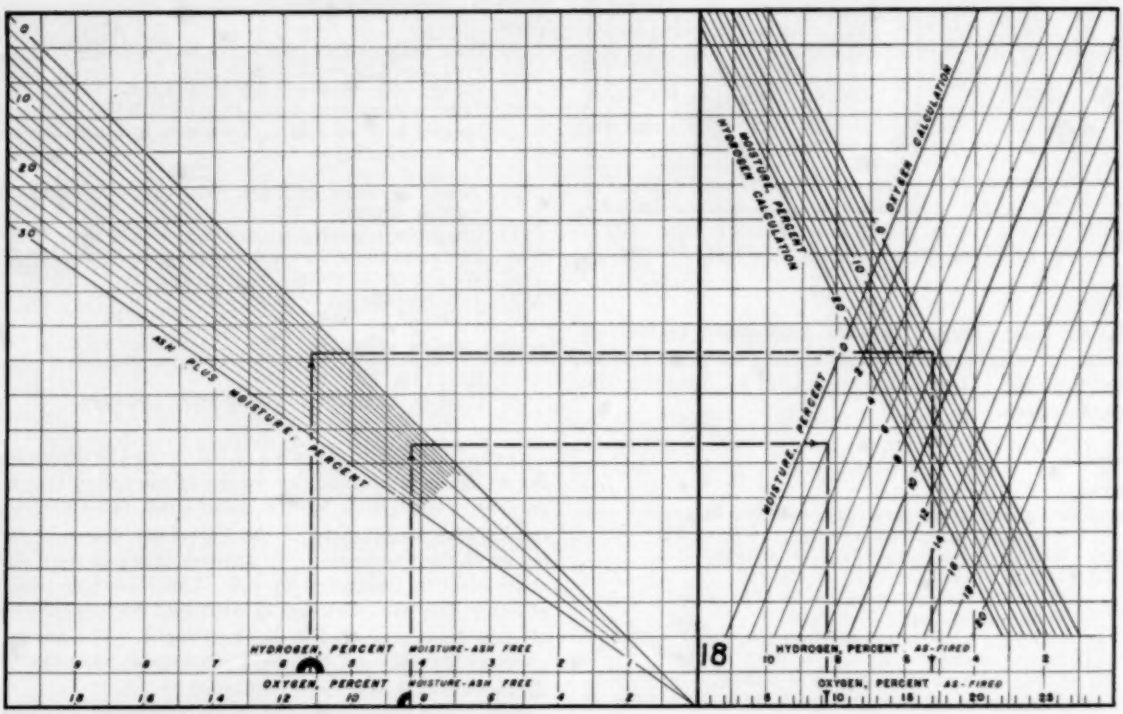

FIG. 9.—Quadrant chart for determining percentage of hydrogen and oxygen on the as-fired basis from the moisture- and ash-free basis. The chart may be used in the reverse order.

Figure 3. Equations (5) and (6)

Given:

(*a*) Temp. of outside air (t_a) = 79.2°F.
(*b*) Temp. of flue gas (t_f) = 340°F.
(*c*) Weight of fuel fired (F) = 1937 lb.
(*d*) Moisture in fuel (m) = 1.9%.
(*e*) Hydrogen in fuel (H) = 5.2%.

To determine:

(*a*) Heat lost due to moisture in fuel.
(*b*) Heat lost due to hydrogen in fuel.

Method: Two factors are used to determine the values shown on this chart. A multiplier of 10 is used for the weight of fuel fired, and another multiplier of 10 is used for the moisture in the fuel; the value for the heat lost from moisture in the fuel therefore must be divided by 100 (10 × 10) and the heat lost from hydrogen in the fuel by 10.

Follow the heavy dash line in the upper quadrant from the vertical line, representing the temperature of the flue gas (340°F), horizontally to the left to the diagonal line, representing the temperature of the outside air (79.2°F), and then vertically downward to the diagonal line, representing the weight of fuel fired (1937 lb.). From this point, follow the heavy dash line horizontally to the left to determine the heat lost from moisture in the fuel and horizontally to the right to determine the heat lost from hydrogen in the fuel. Follow the horizontal dash line to the left to the diagonal line, representing moisture in the fuel (1.9%), and vertically downward to the scale for heat lost from moisture in the fuel (43,000 B.t.u.). Follow the horizontal dash line to the right to the diagonal line, representing hydrogen in the fuel (5.2%), and vertically downward to the scale for heat lost from hydrogen in the fuel (1,055,000 B.t.u.).

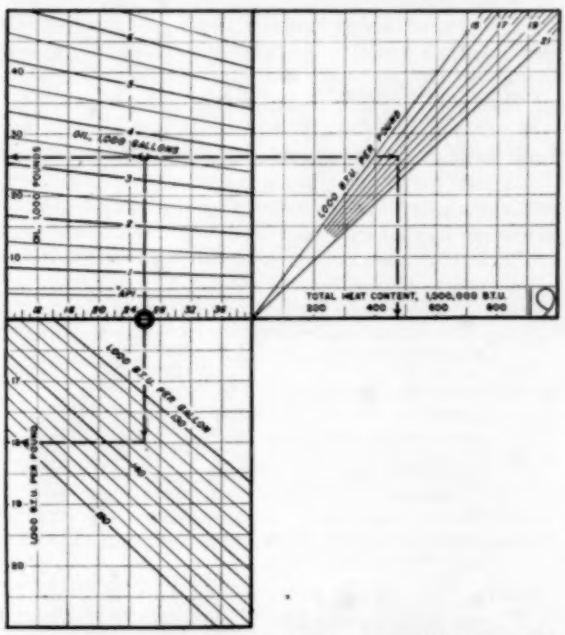

FIG. 10.—Quadrant chart for determining pounds (B.t.u. per pound) and total heat content for fuel oils of different specific gravities (*API*) at 60°F.

Figure 4. Equations (7), (8), and (10)

Given:

(*a*) Carbon in fuel (C) = 76.2%.
(*b*) Sulfur in fuel (S) = 1.9%.
(*c*) Weight of fuel fired (F) = 1937 lb.
(*d*) Ash in fuel (A) = 7.5%.
(*e*) Combustible in refuse (C_a) = 30.4%.
(*f*) Flue-gas analysis (av. %): CO_2 = 3.3, CO = 0.2, O_2 = 16.7, and N_2 = 79.8.
(*g*) Temp. of entering (outside) air (t_a) = 79.2°F.
(*h*) Temp. of flue gas (av.) (t_f) = 340°F.
(*i*) Vapor in entering air (w) = 0.007 lb. per lb. dry air.

To determine:

(*a*) Weight of refuse.
(*b*) Heat lost in refuse.
(*c*) Weight of air supplied.
(*d*) Heat lost due to moisture in entering air.
(*e*) Heat lost in dry flue gas.

Method: A multiplier factor of 10 is used for the weight of fuel fired; all indicated answers must therefore be divided by 10, except for the heat lost from moisture in the entering air, which is divided by 100 because another factor of 10 is used for the last quadrant. The weight of refuse is first determined, using the two smaller upper right quadrants (210 lb.).

The weight of air supplied and the heat lost from moisture in the entering air are determined by a simple eight-quadrant chart with two points of entry. Follow the heavy dash line from the *upper* base line, representing carbon in fuel (76.2%) in the upper left-center quadrant, vertically downward to the diagonal line, sloping to the right, representing sulfur in the fuel (1.9%), and then horizontally to the left. Continue as explained for the previous charts. The second point of entry is the base line, representing the weight of refuse (210 lb. as found from equation (10*a*)) in the quadrant immediately below the starting quadrant. Follow the heavy dash line vertically downward to the diagonal line, representing the combustible in the refuse (30.4%), and horizontally to the left. The weight of air supplied (98,500 lb.) and the heat lost from moisture in the entering air (85,000 B.t.u.) are obtained from their respective horizontal scales.

Follow the heavy dash line from the *lower* base line, representing carbon in fuel (76.2%) in the upper left-center quadrant; vertically upward to the diagonal line sloping to the left, representing sulfur in the fuel (1.9%); horizontally to the right to the line, representing the weight of fuel fired (1937 lb.); vertically downward to the line dividing the two quadrants; diagonally to the left to the point at which it intersects the horizontal line projected from the left, representing heat lost in combustible in refuse; vertically downward to the diagonal line (radial line drawn from the point on the vertical line determined by the simple two-quadrant chart with an entry point on the vertical *oxygen in flue gas* (16.7%) scale contained in the larger lower right quadrant); horizontally to the left to the diagonal line, representing the carbon dioxide plus the carbon monoxide in the flue gas (3.5%); vertically downward to the diagonal, representing the temperature of the flue gas minus the temperature of the outside air (340° − 79.2° = 260.8°F); and finally horizontally to the right to the vertical heat lost in dry flue gas (6,200,000 B.t.u.).

Figure 5. Equation (9)

Given:
(*a*) Weight of fuel fired (F) = 1937 lb.
(*b*) Carbon in fuel (C) = 76.2%.
(*c*) Weight of refuse (B) = 210 lb.
(*d*) Combustible in refuse (C_s) = 30.4%.
(*e*) Carbon monoxide in flue gas (CO) = 0.2%.
(*f*) Carbon dioxide in flue gas (CO_2) = 3.3%.

To determine:
(*a*) Heat lost from CO in flue gas.

Method: A simple five-quadrant chart with two points of entry, from the scales for horizontal weight of fuel fired and the vertical weight of refuse, is used. A multiplier factor of 20 is used for the weights, and a divisor factor of 2 is used in the last quadrant; the indicated answer (8,150,000 B.t.u.) is divided by 10.

Figure 6. Equation (15)

Given:
(*a*) Weight of fuel fired (F) = 1937 lb.
(*b*) Analysis of fuel (%): C = 76.2, H = 5.2, S = 1.9, O = 7.7.

To determine:
(*a*) Weight of air required.

Method: A simple four-quadrant chart is used.

Figure 7. Equation (16)

Given:
(*a*) Oxygen in flue gas (O_2) = 16.7%.
(*b*) Nitrogen in flue gas (N_2) = 79.8%.

To determine:
(*a*) Excess air (%).

Method: Follow the heavy dash line from the vertical scale, representing the oxygen (16.7%) in the right quadrant, horizontally to the left to the point at which it intersects the vertical line projected upward from the horizontal scale, representing the nitrogen (79.8%). The answer is indicated by the diagonal lines. If the oxygen in the flue gas is less than 14%, the left quadrant is used.

Figure 8. Equation (17)

Given:
(*a*) Weight of dry air supplied (R) = 98,500 lb.
(*b*) Vapor in entering air (w) = 0.007 lb. per lb. of dry air.
(*c*) Temp. of entering air (t_a) = 79.2°F.
(*d*) Pressure of moist entering air (Hg) = 30 in. mercury.

To determine:
(*a*) Volume of moist air.

Method: A simple three-quadrant chart is used.

Figure 9. Equation (18)

Given:
(*a*) Hydrogen in fuel (moisture- and ash-free basis) = 5.6%.
(*b*) Oxygen in fuel (moisture- and ash-free basis) = 8.3%.
(*c*) Ash in fuel = 7.5%.
(*d*) Moisture in fuel = 1.9%.

To determine:
(*a*) Total hydrogen (as-fired basis).
(*b*) Total oxygen (as-fired basis).

Method: A simple two-quadrant chart is used. Use the upper horizontal scales for hydrogen determinations and the lower for oxygen determinations.

Figure 10. Equations (19), (20), and (21)

Given:
(*a*) 26°A.P.I. fuel oil.
(*b*) 136,000 B.t.u. per gal.
(*c*) 3500 gal.

To determine:
(*a*) B.t.u. per lb.
(*b*) Weight of oil.
(*c*) Total heat content.

Method: Follow the heavy dash line vertically upward from the horizontal scale, representing 26°A.P.I. in the upper left quadrant, to the diagonal line representing gallons of oil (3500); horizontally to the left to the vertical line, representing pounds of oil (2650) or horizontally to the right to the diagonal line, representing B.t.u. per pound (18,200), and then vertically downward to the horizontal total-heat scale (480,000,000 B.t.u.). From the same starting point (26°A.P.I.), follow the heavy dash line vertically downward to the diagonal, line representing heat per gallon (136,000 B.t.u. per gal.); and horizontally to the left to the vertical scale for B.t.u. per pound (18,200).

The last three examples are not part of the heat balance but were included to illustrate the use of the figures.

SUMMARY OF HEAT BALANCE

Item		Heat (B.t.u.)	(%)	Equation No.
Input				
Fuel		26,700,000	69.2	(1)
From cooling	ware	8,350,000	21.6	(2*a*)
	car refractories	3,250,000	8.4	(2*b*)
	car metal	293,000	0.8	(2*c*)
Total input		38,593,000	100.0	
Useful Heat				
Firing dry ware		17,350,000	45.0	(3)
Removing mechanical water from ware		780,000	2.0	(4)
Total useful heat		18,130,000	47.0	
Heat Losses				
From	chemical water in ware	1,210,000	3.1	(4*a*)
	water in fuel	43,000	0.1	(5)
	water from hydrogen in fuel	1,055,000	2.7	(6)
	moisture in entering air	85,000	0.2	(7)
In dry flue gas		6,200,000	16.1	(8)
From	CO in flue gas	815,000	2.1	(9)
	combustible in refuse	925,000	2.4	(10)
	ware leaving kiln	1,960,000	5.1	(11*a*)
	heating car refractories	4,060,000	10.5	(11*b*)
	car refractories leaving kiln	810,000	2.1	(11*c*)
	heating car metal	345,000	0.9	(12)
	car metal leaving kiln	52,000	0.1	(12*a*)
Heat stored in kiln		Not calculated		(13)
Unaccounted-for losses (by difference)		2,903,000	7.5	(14)
Total heat losses		20,463.000	53.0	

Acknowledgments

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SPALLING OF SILICA BRICK DURING HEATING AND COOLING OF FURNACES*

By J. M. McKinley† and S. M. Phelps‡

Abstract

A study of the spalling of silica brick in service has shown that a cobblestone shape of fracture usually occurs. Inasmuch as this fracture was not secured in laboratory tests, a study was made of the influence of the various heating and cooling treatments to bring about this type of fracture. Several procedures which gave this result are recorded.

I. Introduction

A recent study by Pierce and Austin,[1] which extends the work done by Harvey,[2] throws considerable light on the changes in expansion produced along the length of silica brick during service in the roof of an open-hearth furnace. These authors have shown that there is little danger of spalling a hot roof but that there is danger as the roof is cooled, especially when the temperature falls below 300°C (572°F). Earlier work by Austin and Pierce[3] presents data from which it is concluded that the changes noted in expansion through coke-oven walls after service must certainly result in serious spalling when cooling down between 300° and 200°C (572° and 392°F). Miller[4] indicates the apparent reduction in stresses when brick are insulated. Little attention, however, seems to have been paid to the spalling characteristics of silica brick (from the manufacturer) and their consequent behavior in furnaces, both when heated for the first time and when cooled, if they are withdrawn from service before exhaustion of the refractories.

No adequate simulative spalling test for silica refractories exists, and only limited service observations have been made. The latter condition is largely caused by [illegible]s, metal, and slag reactions which obscure the [illegible]al spalling condition when it does appear. [illegible]ofs, which are not uncommon, occur most frequently during intermittent operation. Operators are not in full agreement as to the proper method of "bringing in" or of cooling down a furnace. Satisfactory equipment to determine the temperature of the refractories is rarely found in plants, and the whole procedure is dependent on rather vague plant practice.

As stated, field observations have been limited; but occasionally circumstances have afforded the opportunity to inspect roofs withdrawn from a campaign after some service and before exhaustion to the point where the evidence of spalling was destroyed. Figure 1 shows an open-hearth roof spalled with definite cobblestone effect on the end of each brick. In this case, the spalling was noted early in the run, but no information was available as to the precise point at which it happened. The roof became thin and lost a definite amount of its possible service. Figure 2 presents the roof condition of another furnace where two kinds of brick were installed in rings; spalling occurred more extensively in one than in the other, indicating that fundamental differences in spalling tendencies do exist between different brick and that thermal treatment which is safe for one kind may not be suitable for another. Again, in this case, the spalling left a cobbled face on the remaining refractory. Numerous other spalled roofs, observed under usual operating temperatures and conditions, reveal this same face effect after spalling.

With this cobbled-face pattern in mind, the results of extensive experimental panel spalling tests were examined. These panels had been submitted to the general routine of the A.S.T.M. panel spalling test for high heat duty fireclay brick,[5] except that no preheating treatment was used. The temperature used for the spalling was 1000°C (1832°F), and the panels were shifted at five-minute intervals. In conducting these tests, it was noted early that, after the first cooling interval, the brick received a marked thermal shock upon next being placed in front of the furnace. Later work involving more frequent reversals of the panels gave more dependable results, but even so it was clear that a special type of test would be required. This was shown further because the order of difference between certain brick of known service position was reversed from the data derived from the test. Inasmuch as the type of fracture obtained (shown in Fig. 3) did not resemble the fracture in service, two groups of special tests were devised with the idea of reproducing the effect most frequently encountered in service.

II. Test Methods and Results

(1) Rate-of-Cooling Studies

The first group of tests was designed to ascertain the rate of cooling from different temperatures which could be used without causing the brick to spall. In this work, regular hand-made 9-inch straights were used, but they

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[1] R. H. H. Pierce, Jr., and J. B. Austin, "Comparison of Thermal Expansion of Used Silica Brick from an Insulated and an Uninsulated Open-Hearth Furnace Roof," *Jour. Amer. Ceram. Soc.*, **19** [10] 276–87 (1936).

[2] F. A. Harvey, "Comparison of Used Silica Brick from Insulated and Uninsulated Basic Open-Hearth Roofs," *ibid.*, **18** [3] 86–94 (1935).

[3] J. B. Austin and R. H. H. Pierce, Jr., "Constitution and Thermal Expansion of Silica Coke-Oven Brick after Service," *ibid.*, **16** [2] 102–106 (1933).

[4] L. B. Miller, "Effect of Insulation on Silica Refractories of an Open-Hearth Steel Furnace Roof," *Bull. Amer. Ceram. Soc.*, **14** [11] 359–64 (1935).

[5] C107–36, Manual of A.S.T.M. Standards on Refractory Materials (November, 1937).

were cut in half, making pieces, $4^1/_2$ by $4^1/_2$ by $2^1/_2$ in., because early work had shown that using the 9- by $2^1/_2$-in. face tended to cause the brick to crack at right angles to the heated face rather than to spall in the

FIG. 1.—Spalled surface of a silica-brick roof.

typical cobblestone style. Twenty-eight pieces were used to lay up a panel, 18 inches square, and these samples were backed up with $4^1/_2$ inches of insulation.

To provide sufficiently slow heating so as not to spall the brick during the rise to the required temperatures, a heavy-gage metal plate was placed close to the test

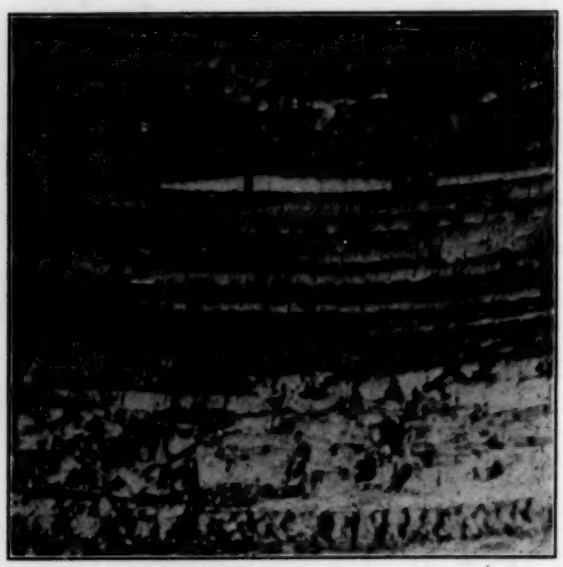

FIG. 2.—Silica roof laid up with two kinds of silica brick showing the difference in their spalling behavior.

surface of the panel, and next to this, facing the furnace, a layer of insulating fire brick $1^1/_4$ inches thick was laid up. This setup was arranged in front of the furnace of the standard panel spalling equipment, a cross-section of which is shown in Fig. 4. Thermocouples were placed (Fig. 4), and the couple measuring the surface temperature was used to control the rate of heating the furnace proper.

Three sets of tests were conducted, using for each set the maximum temperatures of 400°, 600°, and 800°C (752°, 1112°, and 1472°F). In each case, after reaching the maximum temperature of the test on the surface of the test brick, heating was continued until the tem-

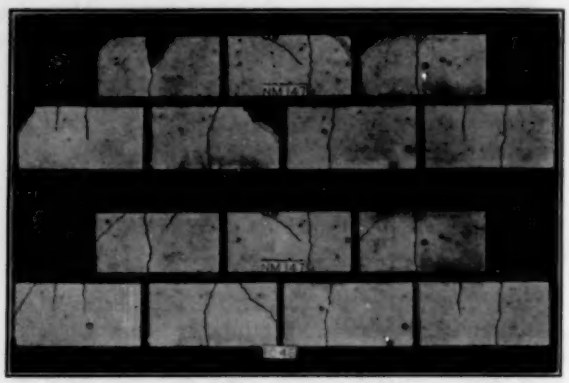

FIG. 3.—Type of spalling fracture obtained from experimental panel spalling test.

perature at the interface of the test brick and insulation approached equilibrium. The panel was then removed from the furnace, and the surface of the test brick was cooled rapidly.

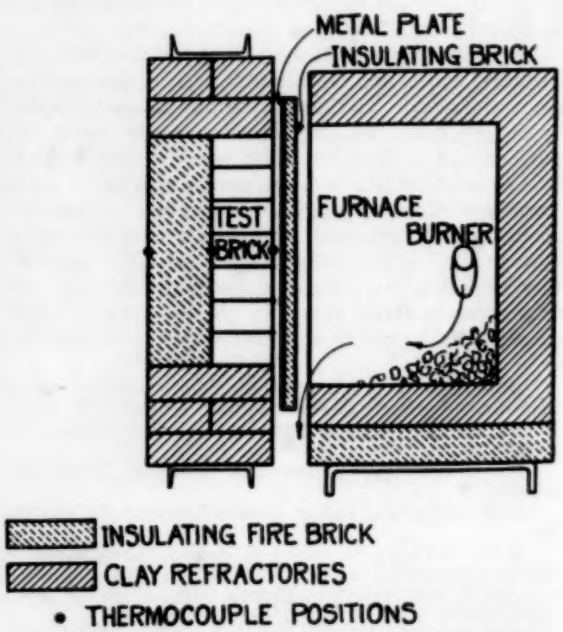

FIG. 4.—Section through furnace showing method of heating the panels for the rate-of-cooling study.

Two methods of cooling were applied to each of these three sets of tests. In the first method, cooling was accomplished by the usual standard panel-spalling air blast but without water mist. In the second method, after

heating the panels at each of the three temperatures previously given, the tests were duplicated, but cooling was carried out by the air blast plus the water mist of the standard panel spalling test.

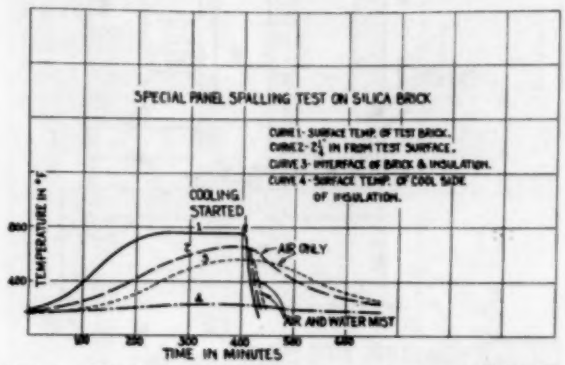

FIG. 5.—Heating and cooling curves of the test brick in the 400°C rate-of-cooling studies.

Figure 5 shows the heating and cooling rates in the 400°C (752°F) test for both methods of cooling. Curve No. 1 shows the temperature on the surface of the test brick; curve No. 2, the temperature half-way between the hot and cold side of the test brick; curve

FIG. 6.—Appearance of brick cooled from 400°C; (*left*) by air blast alone; (*right*) by air with water mist.

No. 3, the interface temperature between the test brick and the insulation; and curve No. 4, the outside temperature of the insulation. Referring to curve No. 1 (at the start of the cooling period), the surface temperature dropped rapidly when both air and air-water mist were used for cooling. Temperature curves Nos. 2 and 3 show that when only air was used the temperature drop was gradual. These contrasted rates of cooling employed in the two methods explain the peculiarities in the spalling results obtained (shown for the 400°C (752°F) test in Fig. 6). The temperature of 400°C did not cause any loss with either method of cooling, but the air-with-water mist method caused considerably more checking than the air alone. In this and in subsequent figures, the air-mist cooled brick are shown on the right-hand side of the photographs.

Figure 7 gives the temperature curves for the 600°C (1112°F) test, and Fig. 8, the condition of the panels after cooling. With air only, eleven brick showed separation of spalled sections and an average loss in these eleven brick of 13%. The air-mist cooling again did not cause separation of pieces, but the amount of checking was increased somewhat over the 400°C (752°F) panel.

The 800°C (1472°F) temperature curves are given in Fig. 9, and the resulting panels are shown in Fig. 10. A pronounced increase in severity of spalling was noted in the air-cooled panel. All twenty-eight brick suffered loss, with an average of 33%. The checking in the

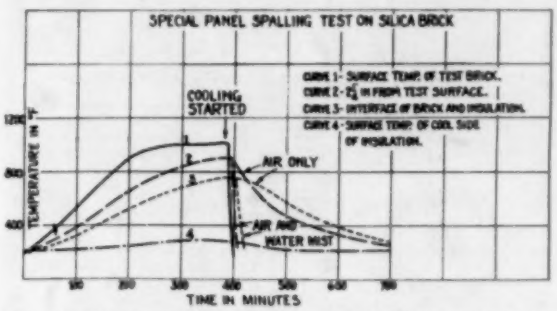

FIG. 7.—Heating and cooling curves of the test brick in the 600°C rate-of-cooling studies.

air-mist cooled panel was very pronounced. Figure 10 is significant because it shows a consistent development of the cobblestone effect in the air-cooled panel.

(2) Rate-of-Heating Studies

The second group of tests was conducted to show the rate at which the brick could be heated without inducing spalling. This involved the construction of a special furnace in which heat applied to the test brick was

FIG. 8.—Appearance of brick cooled from 600°C; (*left*) by air blast alone; (*right*) air with water mist.

conducted through a $1^1/_4$-inch wall of silicon-carbide brick. Figure 11 shows the furnace layout and the position of the thermocouples on the test face of the brick. The silicon-carbide brick wall was used to make possible a gradual and uniform rate of heating, which is difficult to obtain when test brick are exposed directly to the furnace gases.

A number of tests was conducted after adjusting for a uniform distribution of heat through the heating wall of silicon carbide, 18 inches square. The first set of tests in this group was conducted on test pieces, $4^1/_2$

by 4½ by 2½ in., cut from the same lot of 9-inch straights used in the rate-of-cooling studies. In all of the work of the second group, the maximum temperature of the surface of the test brick was 815°C (1499°F), but the time period used to reach this temperature was varied from ½ to 4½ hours. These different heating rates account for marked variations in the amount of spalling that took place.

In the first set of tests outlined, the general cobblestone fracture was obtained. Figure 12 gives the periods of heating, the number of brick spalled with the amount of loss, and the number of checked and unaffected brick. The losses given are not consistent but they have a definite trend.

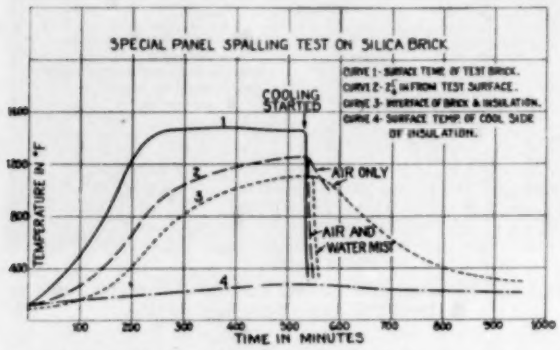

FIG. 9.—Heating and cooling curves of the test brick in the 800°C rate-of-cooling studies.

A second set of tests followed, using pieces of handmade silica brick cut from 13½- by 6- by 3-inch straights. In order to have the same wall thickness when testing, the pieces were cut to 6 by 4½ by 3 inches in size, and the 6- by 3-inch face was exposed for treatment, thus presenting a larger area. The same general thermal procedure was used as in the first set of tests, and the results are given in Fig. 13.

FIG. 10.—(*Left*) Severe spalling caused by air cooling from 800°C; (*right*) stress-relieving cracks produced by air with water-mist cooling.

A final or third set of tests was carried out on pieces, 9 by 4½ by 3 inches, also cut from 13½- by 6- by 3-inch straights, and the 9- by 3-inch faces were exposed to treatment. Figure 14 shows the results. With one hour of heating, the brick broke in half at right angles to the heated face and showed some spalling loss about the corners.

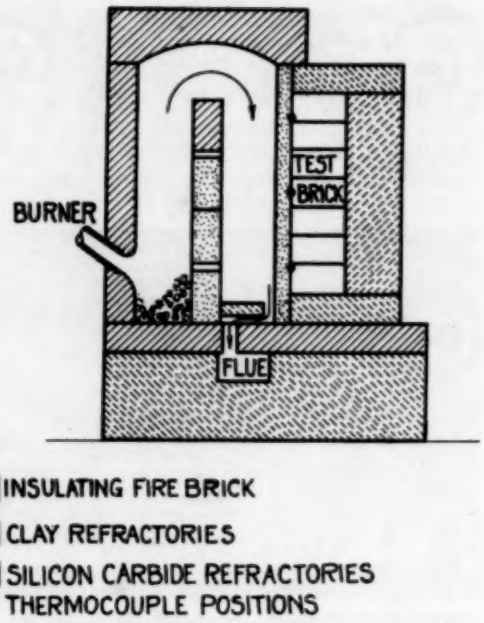

FIG. 11.—Section through furnace used for rate-of-heating study.

Returning briefly to the first set, namely the test pieces, 4½ by 4½ by 2½ inches and heated to 815°C (1499°F) in one hour, Fig. 15 portrays the type of fracture occurring with an average loss of 37% for the

RATE OF HEATING TO 1500°F.			
½ HR	28 Av. Loss 30%	0	0
1 HR.	28 Av. Loss 37%	0	0
1½ HR.	28 Av. Loss 22%	0	0
2½ HR.	18 Av. Loss 38%	10	0
3½ HR.	0	13	15
4½ HR.	0	3	25

FIG. 12.—Results of the rate-of-heating tests on half-brick 2½ by 4½ by 4½ inches; 28 brick tested.

twenty-eight pieces. Here again, and in the entire first set, the cobblestone pattern appears in the form of actual spalling as well as in the direction taken by the cracks prior to definite spalling.

RATE OF HEATING TO 1500°F.			
1 HR.	17 AV. LOSS 28%	1	0
1½ HR.	4 AV. LOSS 30%	14	0
2 HR.	6 AV. LOSS 25%	8	3 1 UNAFFECTED
2½ HR.	0	8	8 2 UNAFFECTED
4 HR.	0	0	0 18 PERFECT

FIG. 13.—Results of the rate-of-heating tests on samples, 3 by 4½ by 6 inches; 18 brick tested.

Figure 16 shows the 6- by 4½- by 3-inch test pieces, set up to reveal the spalling cracks present after treatment under the one-hour rate of heating.

RATE OF HEATING TO 1500°F.			
1 HR.	5	7	0
1½ HR.	2	10	0
2 HR.	0	12	0
4 HR.	0	0	12

FIG. 14.—Results of the rate-of-heating tests on samples, 3 by 4½ by 9 inches; 12 brick tested.

III. Discussion

The data submitted show clearly the effect of cooling from three different temperatures with air, which is comparatively slow, and with air and water-mist, which is very rapid. The air method undoubtedly is more nearly comparable to the usual conditions of service, but the air-water method is interesting because it shows a type of checking or interlocked crazing which, if occurring in service, might render the brick relatively insensitive to thermal shock through relief of stresses. This conceivably takes place in beehive coke ovens. In other words, very rapid cooling breaks up the outer

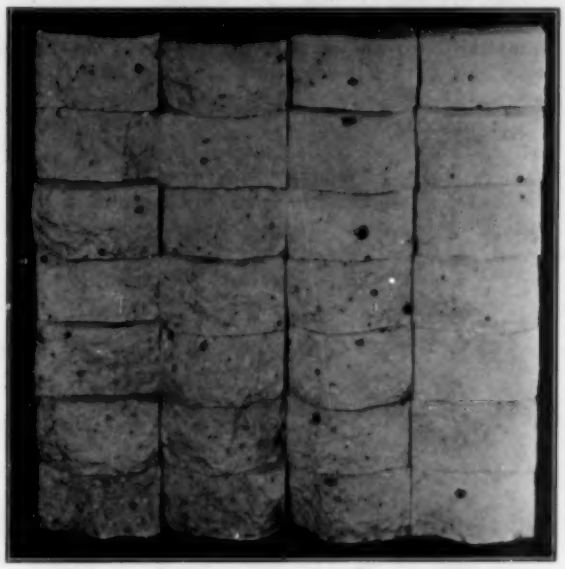

FIG. 15.—Type of fracture occurring in the test pieces, 4½ by 4½ by 2½ inches.

surface of the brick into small areas, thereby allowing the strains to be relieved without complete loss of spalls.

In view of this work, it is doubtful whether any commercial furnace is ever cooled with sufficient rapidity to cause silica brick to spall, except in localized areas of the roof, the walls adjacent to the doors, or other

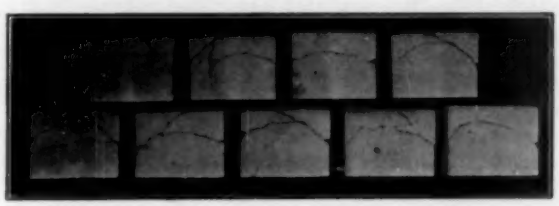

FIG. 16.—The brick (6 by 4½ by 3 inches), after spalling, arranged to show the type of fracture produced by heating to 815°C in one hour.

openings which permit heavy air infiltration. The heat capacity of the larger type of industrial furnace is probably sufficient to cause it to cool slowly enough to prevent spalling. Without question, the spalling that takes place occurs during the heating-up period of operation because it is much easier to heat a furnace too fast than to cool it rapidly.

The different rates of heating, as reported, account for the degree of spalling, and the value of additional work at lower temperature with various rates of heating is indicated.

It has been noted that a change in type of fracture appears in the 6- by 3-inch faces compared with the $4^1/_2$- by $2^1/_2$-inch faces; this change becomes quite marked in the 9- by 3-inch faces, which show development of cracks at right angles to the heat-treated face. This has always been a characteristic of silica brick that are appreciably longer in one dimension than the other. Heating the brick on the long-dimension face causes it to expand and warp, breaking it at right angles rather than relieving the stresses around the corners.

These data should serve as a basis for further investigation into the relationship of the thermal shock to the expansion of quartz, cristobalite, and tridymite in silica brick. The methods employed are readily reproducible, and if the results obtained correlate with service, these methods may be the basis of a simulative service spalling test for silica brick, comparable in practical value to the present A. S. T. M. panel spalling test for fireclay brick.

IV. Conclusions

(1) Under the conditions set up in this work, silica brick will spall in one cooling cycle.

(2) Both air cooling and rapid heating cause the same type of "cobblestone" spalling fracture.

(3) The "cobblestone" fracture obtained in this work is identical with the typical fracture most frequently encountered in service.

(4) The evidence indicates a slight possibility of spalling in commercial furnaces during cooling.

(5) The data show that pronounced spalling action will occur during the heating-up period, provided a sufficiently fast rate of heating is employed.

EFFECT OF SODIUM ALUMINATE ON THE THERMAL EXPANSION OF REFRACTORY CLAY BODIES*

By W. R. Morgan

Abstract

Additions of 2% sodium aluminate to highly siliceous clay-flint bodies fired at cones 13 to 14 appreciably decreased but did not eliminate the cristobalite expansion. A second firing at the same temperature increased the cristobalite expansion, compared with that produced in the first firing, but the expansion in both cases was less than that of the body without the addition of sodium aluminate. A similar addition made to Missouri semi-flint clay increased the cristobalite expansion after one firing but decreased it after a second firing, compared, in both cases, with the expansion of the body to which no sodium aluminate had been added.

I. Introduction

Siliceous clays and bodies would be suitable for many additional uses as refractories except for their characteristic high expansion and low resistance to thermal shock at low temperatures, associated either with the inversion of low to high quartz at 573°C or the inversion of low to high cristobalite in the temperature range from 150° to 250°C. If the silica could be changed to a siliceous glass during firing of the body, the rapid expansion at low temperature would be eliminated and the expansion characteristics of such bodies would be greatly improved.

(1) Review of Literature

It has been shown[1] that cristobalite, which is formed during the firing of clays of low silica content, is converted to a siliceous glass by small amounts of fluxes either present in or added to the clay, although highly siliceous clays do not respond to this treatment. The replacement of cristobalite by siliceous glass eliminates the cristobalite expansion of such clays between 150° and 250°C.

Recent work by Thompson and Parmelee[2] shows that the quartz expansion in highly siliceous Florida clay-flint mixtures fired at cones 13 to 14 can be eliminated by decreasing the particle size of the flint used, because the fine quartz inverts readily to cristobalite and coarse quartz does not. The addition of P_2O_5, B_2O_3, and Fe_2O_3 was found to have little, if any, effect on the formation of glass and the elimination of the cristobalite expansion of the mixtures. Increased firing temperature, however, particularly in the presence of Fe_2O_3, tended to decrease the cristobalite expansion.

(2) Purpose

The purpose of the present study was to determine

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* Presented at the Fortieth Annual Meeting, American Ceramic Society, New Orleans, La., March 31, 1938 (Refractories Division). Received March 31, 1938.

[1] (*a*) T. N. McVay and C. L. Thompson, "X-Ray Investigation of Effect of Heat on China Clays," *Jour. Amer. Ceram. Soc.*, **11** [11] 829–41 (1928).

(*b*) R. A. Heindl, W. L. Pendergast, and L. E. Mong, "Kaolins: Effect of Firing Temperature on Some of Their Physical Properties," *Bur. Stand. Jour. Research*, **8** [2] 199–215 (1932); *Ceram. Abs.*, **11** [6] 387 (1932).

(*c*) R. A. Heindl and W. L. Pendergast, "Fire Clays, Some Fundamental Properties at Several Temperatures," *Jour. Amer. Ceram. Soc.*, **13** [10] 725–50 (1930).

(*d*) R. A. Heindl and W. L. Pendergast, "Progress Report on Investigation of Fireclay Brick and Clays Used in Their Preparation," *ibid.*, **12** [10] 640–75 (1929).

[2] C. L. Thompson and C. W. Parmelee, "Influence of Silica Content upon Properties of Refractories." Thesis for degree of Doctor of Philosophy, Dept. of Ceramic Engineering, University of Illinois, Urbana, Ill., 1936.

the effect of the addition of sodium aluminate on the cristobalite expansion of highly siliceous Florida clay-flint mixtures and on Missouri semiflint clay.

II. Procedure

Commercial Ottawa, Illinois, quartz flint was separated into coarse and fine fractions by sedimentation in water, and the fine fraction (average diameter, 11 microns) was retained for use in the test bodies.

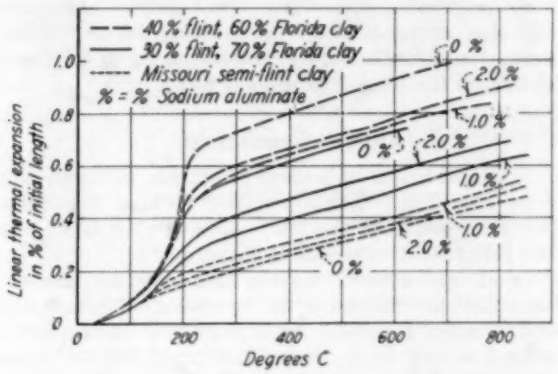
40 % flint, 60 % Florida clay
30 % flint, 70 % Florida clay
Missouri semi-flint clay
% = % Sodium aluminate
Linear thermal expansion in % of initial length
Degrees C

FIG. 1.—Effect of sodium aluminate on thermal expansion of bodies fired once at cones 13 to 14.

Mixtures, containing 30% flint with 70% Florida clay and 40% flint with 60% Florida clay, were blunged with water for six hours and were poured into cloth-lined plaster molds to air-dry. Sodium aluminate, in amounts of 1 and 2% with half as much sugar, was

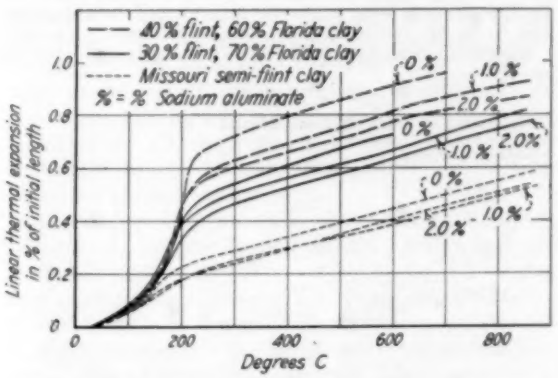
40 % flint, 60 % Florida clay
30 % flint, 70 % Florida clay
Missouri semi-flint clay
% = % Sodium aluminate
Linear thermal expansion in % of initial length
Degrees C

FIG. 2.—Effect of sodium aluminate on thermal expansion of bodies fired twice at cones 13 to 14.

added to small batches of each body. The material was made up to a plastic consistency, and specimens were formed by extrusion.

Similar specimens containing sodium aluminate were prepared from Missouri semiflint clay.

One set of specimens was fired at cones 13 to 14 in a commercial kiln, and a duplicate set was fired twice at the same temperature.

The thermal expansion of the fired bodies was determined by the Fizeau-Pulfrich interferometer method from atmospheric temperature to a maximum temperature of approximately 800°C. The rate of heating was 4°C per minute.

III. Results and Discussion

Sodium aluminate decreased the cristobalite expansion[3] approximately 20% in the body containing 40% flint and approximately 30% in the body containing

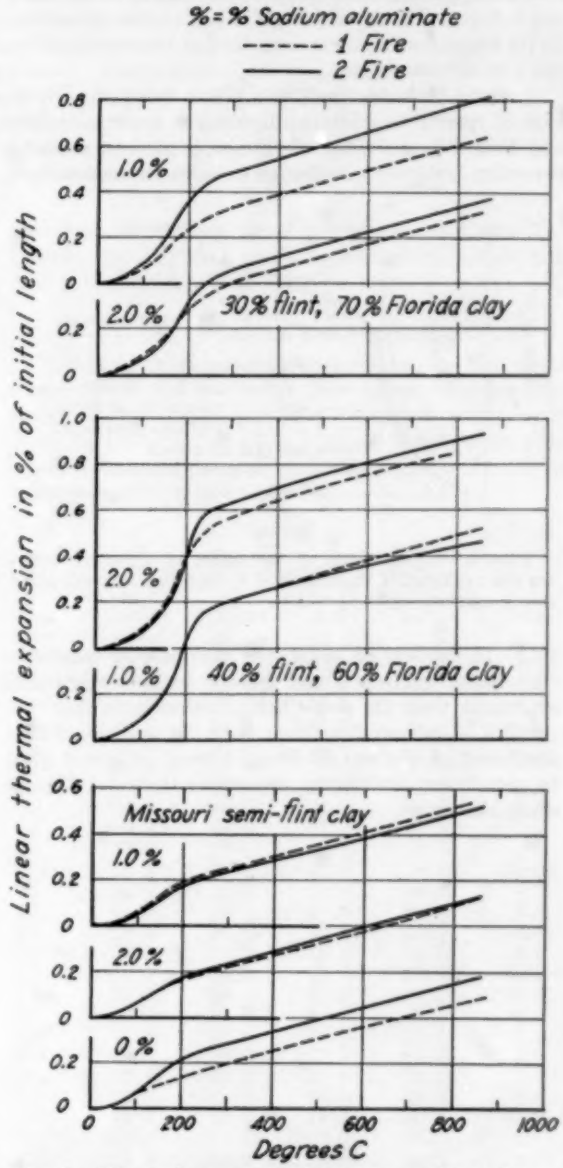
% = % Sodium aluminate
1 Fire
2 Fire
1.0 %
2.0 %
30 % flint, 70 % Florida clay
40 % flint, 60 % Florida clay
Missouri semi-flint clay
Linear thermal expansion in % of initial length
Degrees C

FIG. 3.—Effect of repeated firing at cones 13 to 14 on thermal expansion of bodies.

30% flint, when the bodies were fired once at cones 13 to 14 (Fig. 1). One per cent of sodium aluminate reduced the cristobalite expansion slightly more than when 2% was used.

[3] Expansion curves of untreated bodies taken from thesis by C. L. Thompson and C. W. Parmelee; see footnote 2.

A second firing at cones 13 to 14 decreased the cristobalite expansion of the sodium-aluminate bodies approximately 15% in the body containing 40% flint and approximately 12% in the body containing 30% flint (Fig. 2). The use of 2% of sodium aluminate reduced the cristobalite expansion slightly more than 1%.

The second firing, therefore, tended to increase the cristobalite expansion, compared with the result of a single firing (Fig. 3), although in both cases the cristobalite expansion was less than that of the bodies without sodium aluminate.

It seems probable that, in a single firing the inversion of quartz to cristobalite was not quite complete and that 2% of sodium aluminate tended to promote inversion and gave a higher cristobalite expansion than

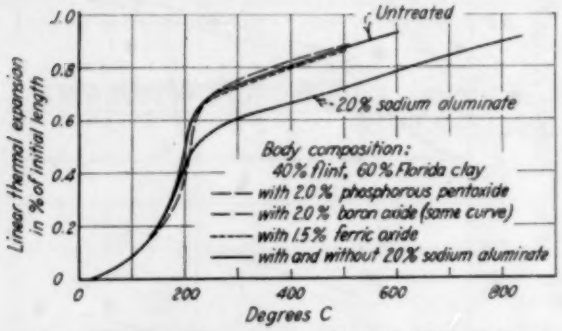

FIG. 4.—Comparison of the effect of different fluxes on the cristobalite expansion of a clay-flint mixture after firing once at cones 13 to 14.

1%. In the second firing, the inversion of quartz to cristobalite continued and gave a higher cristobalite expansion than the single firing, although in this case the 2% of sodium aluminate, with the additional heat treatment of the second firing, formed sufficient glass to give lower cristobalite expansion than did 1% sodium aluminate.

In the case of the Missouri semiflint clay, repeated firings of the untreated clay increased the cristobalite expansion (Fig. 3). Sodium aluminate promoted the formation of cristobalite and increased the cristobalite expansion in a single firing (Fig. 1), but sufficient glass was formed to decrease the cristobalite expansion in the second firing (Fig. 2).

The effects of P_2O_5, B_2O_3, and Fe_2O_3, given by Thompson and Parmelee,[3] are compared after a single firing (Fig. 4) with the effect of 2% sodium aluminate on the body containing 40% flint. Only sodium aluminate had any appreciable effect in reducing the cristobalite expansion of the body, the decrease being of the order of 20% of the total expansion at 250°C.

IV. Conclusions

Small additions of sodium aluminate to highly siliceous clay-flint bodies appreciably reduced the cristobalite expansion of the body, although the effect was not sufficient to eliminate it entirely.

Small additions of sodium aluminate to Missouri semiflint clay promoted the formation of cristobalite and increased the expansion slightly after a single firing; after a second firing, the sodium-aluminate additions promoted the formation of glass and decreased the expansion (compared with that of the untreated clay).

Acknowledgments

Acknowledgment is made to C. W. Parmelee and C. L. Thompson for the use of unpublished data from a thesis; to C. L. Thompson, who arranged for the preparation of the bodies; to C. B. Clark, a student, who prepared the specimens; to the Findlay Clay Products Company for firing the specimens; to the A. P. Green Fire Brick Company for supplying the Missouri semiflint clay; to R. B. Day, a student, who made the expansion determinations; and to G. H. Duncombe, Jr., of the National Aluminate Corporation, who furnished the sodium aluminate for the tests.

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ZINC-VAPOR GLAZING OF CLAYS: I*

Effect of Variable Iron Oxide and Alkalis in Clays on Zinc-Vapor Glaze Colors

By C. Major Lampman and H. G. Schurecht

Abstract

A study was made of the influence of the iron-oxide and alkali contents and absorptions of clay bodies on their ability to take a zinc-green vapor glaze. Although greens may be obtained on bodies with a wide range of compositions and with absorptions up to 8.4% under exacting conditions, the range of bodies which take a green glaze under less favorable circumstances is comparatively small. The probability of obtaining good greens was greatest with those bodies whose absorptions were below 2% and which contained 8 to 18% iron oxide and more than 6% alkalis. Firing to higher temperature and cooling rapidly improved the tendency to produce greens. Desirable tans, browns, brick reds, and grays were obtained by firing to low temperatures and cooling slowly.

I. Introduction

Zinc in its metallic form is used to produce a variety of green colors on red brick by a process similar to salt glazing. These vapor-glaze colors are highly prized for face brick. Because they are glazed, they resist weather and do not become dirt-stained or peeled as porous engobes frequently do.

Desirable zinc greens, however, are difficult to produce, and the yield of first quality brick is seldom more than 60%. Failure to produce good greens on more brick must be ascribed largely to a lack of knowledge of fundamentals in the art of zinc flashing.

Research has been conducted only recently on this subject. Greaves-Walker[1] found that the green color was due to a yellow glaze over a blue-black body instead of the formation of definite green minerals as was formerly believed. The zinc vapor produces a thin, transparent glaze, tinted yellow by iron compounds dissolved from the body. A thin, purplish-blue reduced zone was observed under the glaze. The blue body absorbs most of the long wave-length rays and the yellow glass absorbs most of the shorter wave-length rays. Consequently, the light waves escaping are chiefly those of the middle rays of the light spectrum which are predominantly green.

Although certain red-firing clays take a zinc-green vapor glaze, other red-firing clays do not.[2] It is not definitely known, therefore, what compositions of clay take a green vapor glaze. The degree of vitrification of the body and the rate of cooling, moreover, are believed to influence the color, but no work has been done to show what conditions are most favorable to the development of greens.

The purpose of this investigation, therefore, was to ascertain how zinc-green vapor glazes can be best produced by determining (1) the effect of chemical compositions, (2) the necessary vitrification, and (3) the best methods of vapor glazing and cooling. This paper, the first of a series, is limited to bodies with variable alkali and iron-oxide contents.

II. Material and Methods

Synthetic impure clays were prepared by mixing the respective impurities with pure clays. In the first series of specimens, the alkali contents were varied from 0.9 to 9.4% by adding feldspar to the clays. The iron-oxide contents were varied from 0.8 to 11.1% by adding iron oxide (see Table I).

Table I

Batch Weights of Bodies

	Ga. kaolin	Ky. ball clay	Potter's flint	Buckingham feldspar	Iron oxide
T1	33.3	33.4	33.4		0
T2	32.6	32.7	32.7		2.0
T3	32.0	32.0	32.0		4.0
T4	31.3	31.4	31.3		6.0
T5	30.6	30.7	30.7		8.0
T6	30.0	30.0	30.0		10.0
U1	30.0	30.0	30.0	11.0	0
U2	29.4	29.5	29.3	10.8	2.0
U3	28.8	28.9	28.7	10.6	4.0
U4	28.5	28.5	27.7	10.3	6.0
U5	27.6	27.6	26.7	10.1	8.0
U6	27.1	27.0	26.0	9.9	10.0
V1	26.6	26.7	26.7	22.0	0
V2	26.3	26.3	25.8	21.6	2.0
V3	25.3	25.2	24.4	21.1	4.0
V4	25.2	25.2	23.9	20.7	6.0
V5	24.4	24.2	23.0	20.2	8.0
V6	24.2	24.1	22.0	19.7	10.0
W1	23.5	23.6	23.6	33.0	0
W2	24.0	23.1	22.5	32.3	2.0
W3	22.6	22.6	21.3	31.6	4.0
W4	22.1	22.2	20.2	31.0	6.0
W5	21.7	21.7	19.0	30.3	8.0
W6	21.2	21.2	17.9	29.6	10.0
X1	20.3	20.3	20.3	44.0	0
X2	19.9	19.9	19.0	43.1	2.0
X3	19.5	19.5	17.7	42.2	4.0
X4	19.1	19.0	16.5	41.3	6.0
X5	18.7	18.6	15.2	40.4	8.0
X6	18.3	18.2	13.9	39.5	10.0
Y1	17.0	17.0	17.0	55.0	0
Y2	16.7	16.7	15.6	53.9	2.0
Y3	16.4	16.3	14.2	52.8	4.0
Y4	16.0	16.0	12.7	51.6	6.0
Y5	15.7	15.6	11.3	50.5	8.0
Y6	15.4	15.3	9.9	49.4	10.0

* Presented at the Fortieth Annual Meeting, American Ceramic Society, New Orleans, La., March 29, 1938 (Structural Clay Products Division). Received July 29, 1938.

[1] A. M. Greaves-Walker, "Origin of Color Produced on Red Bodies by Zinc Vapors," *Jour. Amer. Ceram. Soc.*, **14** [8] 578–82 (1931).

[2] H. L. Longenecker, "Vapor Glazing and Color Flashing of Pre-Cambrian Shales," *Brick Clay Rec.*, **77**, 659–66 (1930); *Jour. Amer. Ceram. Soc.*, **13** [11] 794–804 (1930).

The first series of tests indicated that good greens could be produced on clays with more than 11.1% iron oxide; a second series of tests was conducted in which the iron-oxide content was raised to 24.44% (see Table II). The 72 bodies prepared in this

TABLE II

BATCH WEIGHTS OF BODIES

	Ga. kaolin	Ky. ball clay	Potter's flint	Buckingham feldspar	Iron oxide
AA1	29.4	29.3	29.3		12.0
AA2	28.7	28.7	28.6		14.0
AA3	28.0	28.0	28.0		16.0
AA4	27.3	27.3	27.4		18.0
AA5	26.7	26.7	26.6		20.0
AA6	26.0	26.0	26.0		22.0
BB1	26.5	26.5	25.5	9.8	11.7
BB2	25.9	25.9	24.9	9.5	13.8
BB3	25.3	25.3	24.3	9.3	15.8
BB4	24.7	24.7	23.7	9.0	17.9
BB5	24.1	24.1	23.1	8.8	20.0
BB6	23.5	23.5	22.5	8.5	22.0
CC1	23.7	23.7	21.5	19.6	11.5
CC2	23.2	23.1	21.0	19.1	13.6
CC3	22.6	22.6	20.5	18.6	15.7
CC4	22.1	22.0	20.0	18.1	17.8
CC5	21.5	21.5	19.5	17.6	19.9
CC6	21.0	20.9	19.0	17.1	22.0
DD1	20.9	20.8	17.6	29.5	11.2
DD2	20.4	20.3	17.2	28.7	13.4
DD3	19.9	19.8	16.8	27.9	15.5
DD4	19.4	19.4	16.4	27.2	17.7
DD5	18.9	18.9	16.0	26.4	19.8
DD6	18.4	18.4	15.6	25.6	22.0
EE1	18.0	18.0	13.7	39.3	11.1
EE2	17.6	17.6	13.4	38.3	13.3
EE3	17.2	17.1	13.1	37.3	15.5
EE4	16.7	16.7	12.7	36.2	17.6
EE5	16.3	16.2	12.4	35.2	19.8
EE6	15.9	15.8	12.1	34.2	22.0
FF1	15.2	15.2	9.8	49.1	10.7
FF2	14.8	14.8	9.6	47.8	13.0
FF3	14.5	14.4	9.3	46.6	15.2
FF4	14.1	14.1	9.1	45.3	17.5
FF5	13.8	13.7	8.8	44.0	19.7
FF6	13.4	13.3	8.6	42.7	22.0

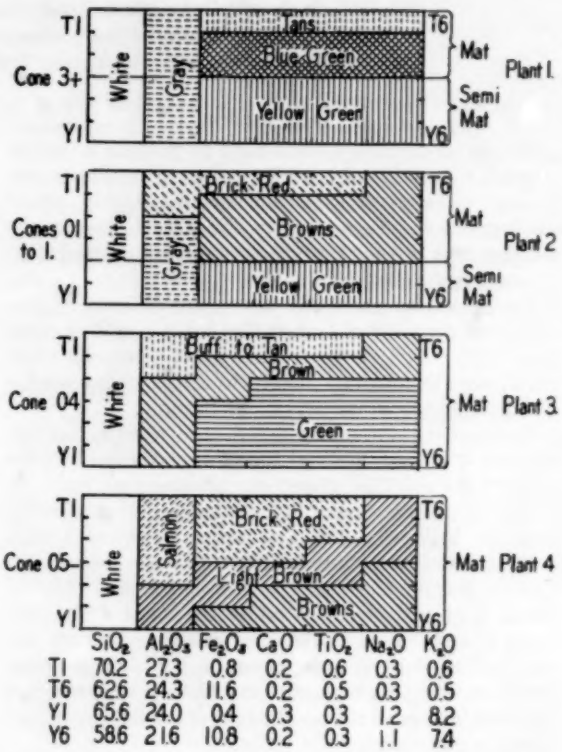
series were molded into cylinders, 2 by ½ inch, in an extrusion machine, and the dried specimens were mounted in refractory plaques. These were subjected to zinc-flashing tests both in laboratory and in commercial kilns. Because the colors obtained in laboratory kilns did not correspond to those produced in commercial kilns, this study is limited to work done in commercial kilns which was considered to be of most practical value.

III. Plant Tests

The vapor glazing of the specimens with zinc was conducted at four plants as follows:

Plant No. 1

A 32-foot round downdraft kiln firing 198.9 tons of brick was employed with a high volatile coal containing 39.52% volatile matter and 56.04% fixed carbon. The test plaques were set in the top of the kiln. It was fired under oxidizing conditions until 30 minutes before flashing when heavy reduction was maintained. Flashing was started about three hours after cone 03 had been reached in the top of the kiln. Ten pounds of scrap zinc were then thrown in each of the twelve fire boxes. The firebox openings were then closed with coal for one hour with the damper open wide enough to keep the smoke from backing out. After stirring the fires thoroughly, flashing was repeated a second and a third time. After the third flashing, the top and bottom openings were sealed with brick and plastered tight with clay. The bottom firebox eyes were opened after 45 minutes, and the fires were stirred from the bottom to volatilize the zinc more thoroughly. After



	SiO_2	Al_2O_3	Fe_2O_3	CaO	TiO_2	Na_2O	K_2O
TI	70.2	27.3	0.8	0.2	0.6	0.3	0.6
T6	62.6	24.3	11.6	0.2	0.5	0.3	0.5
YI	65.6	24.0	0.4	0.3	0.3	1.2	8.2
Y6	58.6	21.6	10.8	0.2	0.3	1.1	7.4

FIG. 1.—Effect of Fe_2O_3 and K_2O on zinc-flash colors.

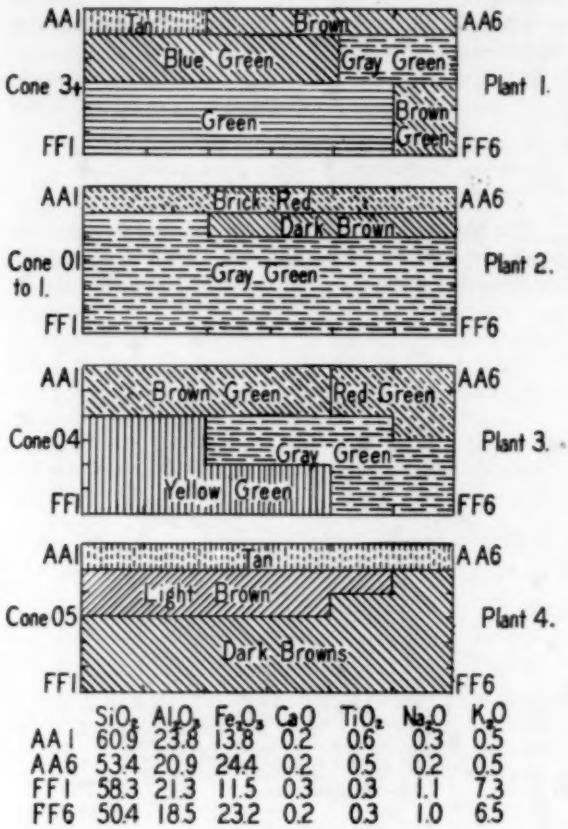
30 minutes, the top eyes were opened and the fire was stirred from the top. The kiln was then connected to a waste-heat drier, the doors were taken down, and a fan was used to blow the heat from the kiln as rapidly as possible. The test plaques showed cone 3 down flat.

Plant No. 2

A 32-foot round downdraft kiln was used with a high volatile coal. Two 125-pound charges of moss zinc were employed. After each charge, the damper was closed for 20 minutes and then opened for 20 minutes; the time interval between charges was also 20 minutes. At the end of the firing, the kiln was kept closed for 8 hours, allowing the temperature to drop about 45° per hour, after which it was connected to a waste-heat drier. The test plaques showed cones 01 to 1 down.

Plant No. 3

A 30-foot round downdraft kiln was used with a high volatile coal. The test plaques were set near the top of the kiln. A reducing kiln atmosphere was maintained before flashing, and this was started when



	SiO_2	Al_2O_3	Fe_2O_3	CaO	TiO_2	Na_2O	K_2O
AA1	60.9	23.8	13.8	0.2	0.6	0.3	0.5
AA6	53.4	20.9	24.4	0.2	0.5	0.2	0.5
FF1	58.3	21.3	11.5	0.3	0.3	1.1	7.3
FF6	50.4	18.5	23.2	0.2	0.3	1.0	6.5

FIG. 2.—Effect of Fe_2O_3 and K_2O on zinc-flash colors.

cone 011 was down in the bottom. Sixty pounds of moss zinc were used for each of three charges putting six pounds in each fire box. Prior to flashing, the stack damper was closed and the firebeds were tightened to retard the passage of air. The stack damper remained closed for three minutes after the first charge of zinc was added. It was then raised for two minutes to clear the kiln. This alternate closing and opening of the damper was continued for 20 minutes. When the temperature started to drop, the second charge of zinc was added, using the same stack-damper control as was employed for the first flashing. A third charge was then added and controlled in a similar manner, after which the fires were drawn, the crown cover was removed, and the door was taken down as soon as possible. A fan was used to increase the rate of cooling after reaching a dull red heat. The test plaques showed cone 04 down after removal from the kiln.

Plant No. 4

A 68-foot rectangular downdraft kiln, firing 431 tons of brick and employing a high volatile coal, was used. A reducing period of 22 hours was maintained before flashing. The ware was first salt-glazed three times. This was followed by vapor-glazing twice, using a mixture of 12 pounds of scrap zinc and 6 pounds of salt to each fire box, making a total of 576 pounds of zinc. A draft-gage reading of −2.0 was maintained at the kiln during flashing. Forty-minute intervals elapsed between the charges. Cooling took place slowly with the dampers closed for the first six hours; then the dampers were opened. Cone 05 was down on the test plaque after removal from the kiln.

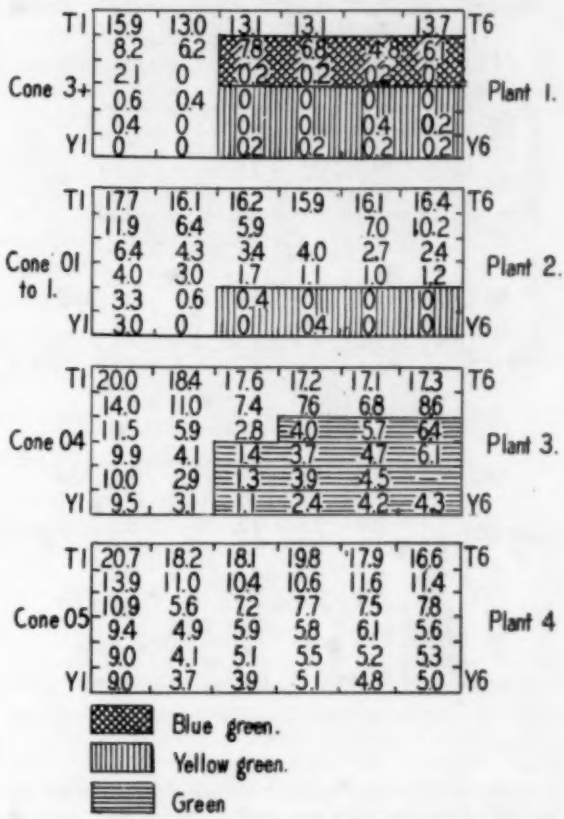


FIG. 3.—Effect of absorptions of bodies on zinc-flash colors.

The glazed specimens were examined for color,[3] and their water absorptions were determined after two hours of boiling.

IV. Results

The results are shown graphically in Figs. 1 to 4. The cones given in the charts are those observed on the test plaques after their removal from the kilns. The cone observed before flashing was 6 to 7 cones lower than that on the test plaque after flashing. The

[3] Standard Mullikan color charts published by John Wiley & Sons were consulted in naming the colors.

areas of composition in which the different colors were obtained are shown by various kinds of shading. The water absorptions of the different bodies are shown in Figs. 3 and 4.

V. Discussion of Results

It is apparent that blue-greens may be produced on bodies with less than 7.8% absorption when these contain 3 to 4% alkalis and 3 to 19% iron oxide. Yellow-greens were obtained on bodies with less than 5.7% absorption when these contained 4 to 9% alkalis

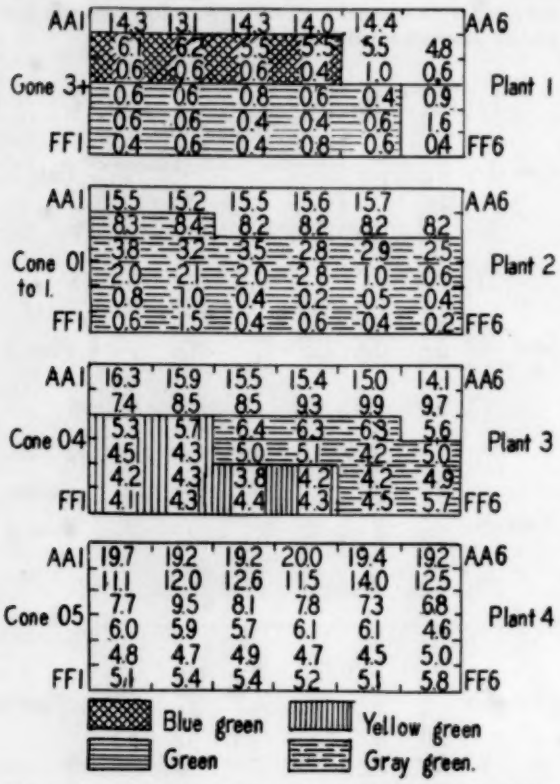


FIG. 4.—Effect of absorptions of bodies on zinc-flash colors.

and 3 to 20% iron oxide. Regular greens were obtained on bodies with less than 6.4% absorption when these contained 4 to 9% alkalis and 5 to 21% iron oxide. Gray-greens were produced on bodies with less than 8.4% absorption when these contained 2 to 9% alkalis and 14 to 24% iron oxide.

At plants No. 1 and No. 3, the kilns were cooled rapidly, and a large percentage of the specimens developed green colors. At plants No. 2 and No. 4, however, the kilns were cooled slowly, and comparatively few of the specimens developed a green color.

It is evident that greens may be obtained on bodies with a wide range of compositions and with absorptions up to 8.4% under exacting conditions. Under less favorable circumstances, however, the range of bodies which take a green color is comparatively small. The probability that a body will take a green vapor glaze, under widely varying conditions of vapor glazing encountered in practice, is therefore important in the analysis of these results.

This was done by classifying the specimens, fired at the four plants, into groups with varying iron-oxide and alkali contents. These were further subdivided into groups with 0 to 2, 2 to 5, and 5 to 9% absorptions, respectively. The following equation was used to calculate their probability of taking a green vapor glaze:

$$P = \frac{a}{a+b}$$

P = probability of taking a green vapor glaze.
a = specimens which took a green vapor glaze.
b = specimens which did not take a green glaze.

The results of this analysis are shown as solid diagrams in Fig. 5. It is apparent that the probability of obtaining greens is greatly improved by keeping the

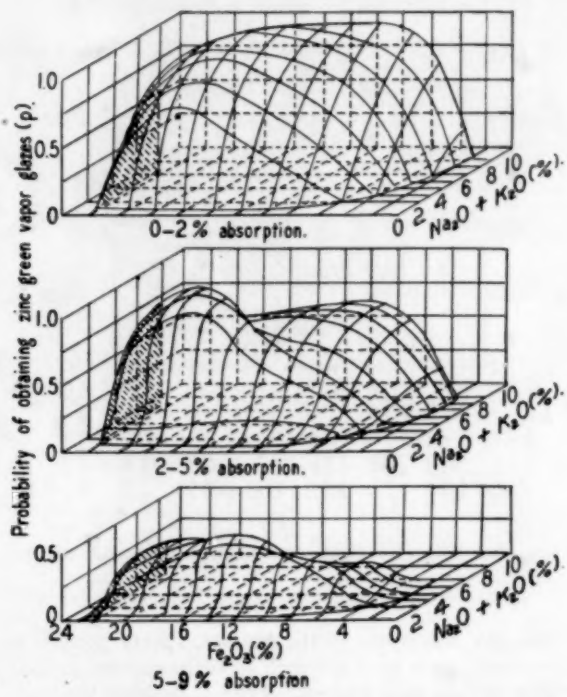


FIG. 5.—Effect of variable iron-oxide and alkali contents and absorptions on the probabilities of obtaining zinc greens.

absorptions below 2%. In no case were greens obtained on bodies with more than 8.4% absorption. The probability of obtaining greens is best with 8 to 18% iron oxide and with more than 6% alkalis.

Other desirable colors than greens, however, were also produced by zinc-vapor glazing. With bodies containing less than 1% iron oxide, the color was white in all cases. Tans were obtained on bodies with 11 to 18.4% absorption when they contained 1 to 16% iron oxide and 1 to 4% alkalis. Grays were produced on bodies with less than 13% absorption

when they contained 1 to 3% iron oxide and 0 to 9% alkalis. Browns were obtained on bodies with 1 to 16.6% absorption when they contained 3 to 24% iron oxide and 0 to 9% alkalis. Brick reds were produced on bodies with 7.2 to 19.8% absorption when they contained 1 to 9% iron oxide and 0 to 4% alkalis.

Brick reds were obtained only at plants No. 2 and No. 4, where the cooling was conducted at a slow rate. A large percentage of specimens glazed at these plants was also brown and tan. It is evident, therefore, that slow cooling promotes the formation of brick red, tan, and brown zinc-flash colors.

VI. Summary

This summary applies to clays with 50 to 70% silica and 18.5 to 27.5% alumina.

(1) Under favorable conditions of firing and cooling, greens in yellow, blue, and gray shades were obtained on bodies with less than 8.4% absorption when they contained 2 to 9% total alkalis and 3 to 24% iron oxide. The probabilities of obtaining greens are best when the absorptions are less than 2% and when the body contains between 8 and 18% iron oxide and more than 6% alkalis.

(2) Under certain conditions, zinc-flash tans were obtained on bodies with 11 to 18.4% absorption when they contained 1 to 16% iron oxide and 1 to 4% alkalis.

(3) Grays were produced on bodies with less than 13% absorption when they contained .1 to 3% iron oxide and 0 to 9% alkalis.

(4) Browns were obtained on bodies with 1 to 16.6% absorption when these contained 3 to 24% iron oxide and less than 9% alkalis.

(5) Brick reds were produced on bodies with 7.2 to 19.8% absorption when these contained 1 to 9% iron oxide and less than 4% alkalis.

(6) Firing the specimens to higher temperatures caused a larger number of specimens to develop green glazes.

(7) Rapid cooling promotes the formation of green vapor glazes, and slow cooling promotes the development of brick reds, browns, and tans.

Acknowledgments

The writers wish to acknowledge their indebtedness to the Cherokee Brick Co., Macon, Ga.; the Claycraft Co., Columbus, Ohio; the Glen-Gery Shale Brick Co., Harrisburg, Pa.; and the Hydraulic-Press Brick Co., St. Louis, Mo., for the use of their facilities and cooperation in this work. The writers are also grateful to M. E. Holmes for his helpful suggestions in this work.

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CONE FUSION STUDY OF MIXTURES OF ZIRCONIUM SILICATE, SILICA, AND ALUMINA*

BY ROBERT F. REA

ABSTRACT

Alumina and alumina-silica mixtures have a strong fluxing effect on zirconium silicate. A eutectic between $ZrSiO_4$ and Al_2O_3 occurs at approximately 20% Al_2O_3 and melts at cone 31. The ternary eutectic has an approximate composition of 70% SiO_2, 15% $ZrSiO_4$, 15% Al_2O_3, and a P.C.E. of cone 27.

I. Introduction

Zirconium silicate, occurring in nature as the mineral zircon, is finding increasing use as a refractory material. The melting point of pure zirconium silicate has been reported to be over 4000°F, which is considerably higher than the common refractory materials, except for magnesium oxide. Owing to the rather low and uniform thermal expansion, articles made of zircon are exceptionally resistant to spalling. Other properties that make zircon a desirable material for ceramic use are hardness (7 to 8 Moh's scale), high dielectric strength, and resistance to acid slags.

In the development of refractory articles of refined zircon, it was observed that both clay and calcined kyanite fused readily with zircon at a temperature of about 3000°F, forming a fluid melt. Various investigators who have worked with zircon state that clay can not be used with zircon where high refractoriness and load-bearing ability are desired.

* Scheduled for presentation at the Forty-First Annual Meeting, American Ceramic Society, Chicago, Ill., April 16–22, 1939 (Refractories Division). Received January 21, 1939.

II. Literature Review

There has been no information published on melting binary mixtures of zirconium silicate and alumina or of melting ternary mixtures of zirconium silicate, alumina, and silica. Zirnowa,[1] studying the system, ZrO_2–SiO_2, found that the addition of about 6% ZrO_2 (by weight) to SiO_2 lowered the melting point only about 10°C; further additions increased the melting point until the composition of zirconium silicate was reached.

III. Experimental Work

In this paper, the results of P.C.E. determinations on mixtures of $ZrSiO_4$, Al_2O_3, and SiO_2 are given. Small test cones were made of various mixtures of C.P. zirconium silicate, C.P. aluminum oxide, and 200-mesh Ottawa

[1] (*a*) N. Zirnowa, "Melting Diagram of the System ZrO_2–SiO_2," *Z. anorg. allgem. Chem.*, **218** [2] 193–200(1934); p. 194; *Ceram. Abs.*, **13** [9] 243(1934).
(*b*) For diagram, see Fig. 203 of "Supplement to 'Compilation of Phase Rule Diagrams of Interest to the Ceramist and Silicate Technologist,'" *Jour. Amer. Ceram. Soc.*, **21** [4] 113–64(1938); p. 122.

silica, which had been purified by washing in hot hydrochloric acid. The zirconium silicate analyzed 99.5% $ZrSiO_3$ and was ground to pass a 325-mesh screen. The standard A.S.T.M. procedure was followed throughout.

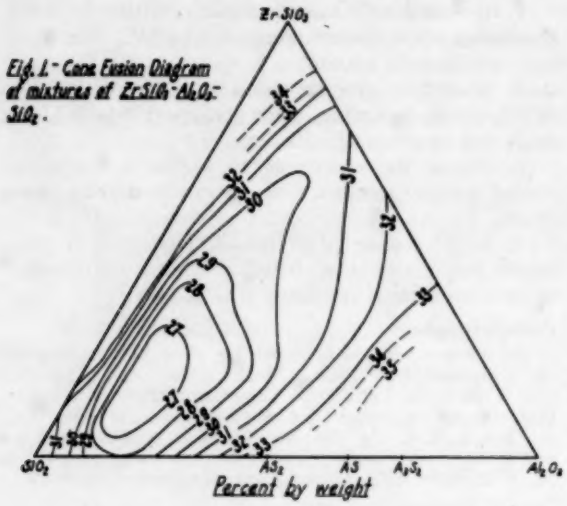

Fig. 1.—Cone Fusion Diagram of mixtures of $ZrSiO_3$-Al_2O_3-SiO_2.

The test cones were calcined at cone 10 before mounting in plaques. Ten per cent intervals were tested, and in a few cases where it was thought necessary 5% intervals were chosen.

The firings were carried out in a gas-fired Mellon Institute type P.C.E. furnace.[2]

The results are given in Fig. 1; numbers on the diagram indicate the fusion point in terms of Orton cones.

IV. Discussion

A ternary eutectic appears in the region near 70% silica, 15% zirconium silicate, and 15% alumina and melts at cone 27 (2920°F). A binary eutectic between $ZrSiO_3$ and Al_2O_3 occurs at approximately 20% Al_2O_3 and melts at cone 31.

Of particular importance is the sharp lowering of the melting temperature of zirconium silicate and silica mixtures when a small amount of alumina is added. The addition of 20% alumina to zircon lowers the melting point from over 4000°F to about 3050°F; 30% kaolin added to zircon has a similar effect.

It is well known that mixtures high in silica tend to be very viscous. Zirconium silicate acts much like silica, and mixtures high in $ZrSiO_3$, containing less than 20% alumina, are also very viscous. Increasing the alumina gives fluid melts and short deformation ranges to the cones.

Denver Fire Clay Company
Denver, Colorado

[2] Vance Cartwright and S. M. Phelps, "A Portable Pyrometric Cone Equivalent Furnace," *Jour. Amer. Ceram. Soc.*, **14** [1] 1–7 (1931).

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CERAMIC ABSTRACTS

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The bold-face number following the journal name is the volume; the issue number is in brackets, followed by the page numbers, then the year in parentheses.

March, 1939
18—3

Abrasives

Artificial corundum. G. Lanorville. *Nature* [Paris], No. 3031, pp. 111–13 (1938).—L. considers the manufacture of this product. R.W.D.

Carborundum tint. Richard Hood. *Magazine of Art*, **31** [11] 643 (1938).—H. describes a new printmaker's process developed in the Philadelphia Print Department of the Federal Art Project. Carborundum in various grades of fineness is ground on the surface of a burnished copper plate to make an ink-holding background that produces a soft texture on the print. M.E.P.

PATENTS

Abrasive article. R. P. Carlton (Stratmore Co.). U. S. 20,946, Dec. 13, 1938 (July 14, 1938); reissue of original U. S. 1,686,898, Oct. 9, 1928.

Abrasive drum for leather-surfacing machines. E. H. Van Valkenburgh. U. S. 2,141,962, Dec. 27, 1938 (Feb. 2, 1938).

Abrasive particle imbedding method. Rodolphe Stahl. Can. 377,783, Nov. 15, 1938 (Jan. 2, 1937; in U. S., Jan. 25, 1936). G.M.H.

Abrasive wheel and its manufacture. F. J. Tone (Carborundum Co.). U. S. 2,143,636, Jan. 10, 1939 (Dec. 4, 1935). The method of making an abrasive wheel comprises lining the interior surface of a mold barrel with a thin strip of abrasive sheet material disposed with the nonabrasive backing adjacent the interior surface of the mold barrel and with the abrasive particles projecting into the interior of the mold, filling the interior of the mold with a hardenable plastic material, pressing the plastic material against the abrasive strip with hot platens, hardening the plastic material, and removing the nonabrasive layer from the outer surface of the abrasive coating.

Apparatus for grinding metallic articles. H. H. Giles (D. T. Giles). U. S. 2,139,952, Dec. 13, 1938 (Aug. 26, 1936). Apparatus for grinding small selected areas of thin flat metal sheets.

Automatic steady rest for grinding machines. George Crompton, Jr. (Norton Co.). U. S. 2,141,596, Dec. 27, 1938 (Nov. 19, 1936).

Brake drum grinding. H. K. Bigelow (B. S. Lurie). U. S. 2,142,710, Jan. 3, 1939 (Oct. 9, 1937).

Buffing wheel. E. E. Murray (J. W. Myers and L. W. MacFarland). U. S. 2,140,208, Dec. 13, 1938 (March 17, 1934; renewed Feb. 3, 1936). A buffing disk comprises a relatively thin center portion provided with a central opening and a relatively thicker annular portion about the center portion having an annular zone which is provided with one or more passages leading outwardly from the center portion.

Casting matrices for use in making bonded abrasive gear wheels. Carborundum Co. Brit. 496,251, Dec. 7, 1938 (June 1, 1936).

Collapsible receptacle for cylinder boring and honing operations. D. W. Freborg and S. H. Freborg (Carl G. Freborg). U. S. 2,143,912, Jan. 17, 1939 (Feb. 2, 1938).

Crankshaft grinding machine. J. I. Garside and C. G. Flygare (Norton Co.). U. S. 2,142,050, Dec. 27, 1938 (March 26, 1937).

Cutter grinding machine. Kurt Zwick (Friedrich Deckel Prazisionsmechanick und Maschinenbau). U. S. 2,144,095, Jan. 17, 1939 (July 16, 1936).

Drill-grinding machine. R. P. Stocking (William Sellers & Co., Inc.). U. S. 2,142,923, Jan. 3, 1939 (Aug. 5, 1936).

Expansible polishing wheel. William Krause (Niles-Bement-Pond Co.). U. S. 2,142,873, Jan. 3, 1939 (Sept. 28, 1937).

Grinding device. A. I. Dunn (Cedar Rapids Engineering Co.). U. S. 2,139,887, Dec. 13, 1938 (March 1, 1937). In a grinder, a grinder head, means for determining the axis of rotation of the grinder head with respect to the work, and other means for minimizing undesirable vibrations and oscillations of the grinder head comprising a weight journalled on the grinder head, means for preventing the weight from rotating with the head, and a means for driving the grinder head flexibly connected thereto whereby vibrations of the motor are not transmitted to the grinder head and vibrations of the grinder head are not transmitted to the motor.

Grinding fixture. P. E. LEHMAN. U. S. 2,141,187, Dec. 27, 1938 (Nov. 8, 1935).

Grinding machine. C. E. BROWN (Cincinnati Grinders, Inc.). U. S. 2,141,853, Dec. 27, 1938 (Jan. 18, 1936). H. W. DUNBAR AND H. S. INDGE (Norton Co.). U. S. 2,142,020, Dec. 27, 1938 (Aug. 13, 1937). F. S. HAAS AND WINTHROP TRIBLE (Cincinnati Grinders, Inc.). U. S. 2,141,065, Dec. 20, 1938 (June 1, 1937). D. R. HALL (Gardner Machine Co.). U. S. 2,142,444, Jan. 3, 1939 (Dec. 26, 1935). CHARLES HERFURTH (Cincinnati Grinders, Inc.). U. S. 2,142,028, Dec. 27, 1938 (Sept. 7, 1937).

Grinding machine. ERNEST A. HALL (Hall Mfg. Co.). Can. 378,556, Dec. 27, 1938 (May 22, 1937). G.M.H.

Grinding wheel. NILS G. ANDERSON AND AXEL F. T. LOFQUIST (Norton Co.). Can. 377,303, Oct. 25, 1938 (Dec. 2, 1935). G.M.H.

Increasing the efficiency of resin-bonded grinding wheels. J. R. ERICKSON (Norton Co.). U. S. 2,142,049, Dec. 27, 1938 (Aug. 24, 1938). The method of increasing the life and efficiency of polymerized synthetic resin bonded grinding wheels comprises heating the wheels immediately after manufacture thereof to a temperature that will drive out substantially all the contained moisture thereof, then sealing the wheels to prevent access of further moisture from the air or otherwise, and at a later date unsealing the wheels and using them forthwith to grind.

Internal grinding machine. H. H. ASBRIDGE (Churchill Machine Tool Co., Ltd.). U. S. 2,144,043, Jan. 17, 1939 (March 21, 1938).

Knife-sharpening machine. WILLIAM BLANKNER (Keen-O-Matic Machine Co.). U. S. 2,142,105, Jan. 3, 1939 (Nov. 11, 1935).

Lapping device. R. R. SEARLES (Fafnir Bearing Co.). U. S. 2,141,491, Dec. 27, 1938 (Aug. 6, 1937).

Lapping machine. G. E. HULBERT AND H. S. INDGE (Norton Co.). U. S. 2,142,057, Dec. 27, 1938 (May 23, 1936).

Lawn mower sharpener. S. A. MCKITTRICK. U. S. 2,141,359, Dec. 27, 1938 (Oct. 18, 1937).

Lens-grinding machine. LOWELL L. HOUCHIN. Can. 377,487, Nov. 1, 1938 (July 10, 1936); see U. S. 2,070,733 (*Ceram. Abs.*, **16** [4] 107 (1937)). G.M.H.

Machine for grinding drill bits. FATE DIXON (S. A. Poole). U. S. 2,139,938, Dec. 13, 1938 (Dec. 4, 1937).

Machine for grinding, glazing, or polishing knife blades, etc. A. V. HAGUE, JR. Brit. 495,823, Nov. 30, 1938 (April 20, 1937).

Machine for grinding valve seats. SOC. PARISIENNE D'OUTILLAGE ELECTRIQUE. Brit. 496,635, Dec. 14, 1938 (May 14, 1937).

Making articles of ceramic-bonded granular material. C. H. QUICK AND M. F. BEECHER (Norton Co.). U. S. 2,140,650, Dec. 20, 1938 (Jan. 29, 1934). The method of making an article of ceramic bonded granular material comprises, in addition to selecting the required size and kind of grains and the type of ceramic bond to be used, the steps of measuring out accurately those quantities of the grains and the raw bond, taking into account the shrinkages involved in firing the mass, which will respectively occupy predetermined volumes in the final fired product, mixing the raw bond and grains with that amount of water which will provide the required viscosity to hold the grains in suspension in the water and bond but insufficient to form a castable fluid mass, and dispersing and stabilizing gas therein in an amount required to make a castable fluid mass of that weight per unit of volume of the wet mass which will give the required density of the fired article, the final pore volume being determined by the volume occupied by the gas and water in the wet mass, thereafter pouring the mass into a mold and casting an article therefrom, drying the article, and firing it to mature the bond.

Manufacture of abrasive articles. W. J. TENNANT (Carborundum Co.). Brit. 497,006, Dec. 21, 1938 (May 11, 1937).

Means for grinding worms. O. P. LIVELY (Cone Worm Gear Corp.). U. S. 2,144,459, Jan. 17, 1939 (Aug. 10, 1936).

Method and means for lapping conical surfaces. G. F. JOHNSON (Chrysler Corp.). U. S. 2,139,896, Dec. 13, 1938 (June 3, 1935).

Millstone. JAMES H. ZACHARY (Harry R. Hinman). Can. 377,455, Nov. 1, 1938 (May 19, 1938). G.M.H.

Polishing disk. P. W. DEMPSEY (Westinghouse Air Brake Co.). U. S. 2,142,182, Jan. 3, 1939 (April 6, 1936).

Polishing machine. H. S. INDGE (Norton Co.). U. S. 2,142,058, Dec. 27, 1938 (Dec. 10, 1937).

Process and abrasive for finishing granite. R. B. PERRY (Rock of Ages Corp.). U. S. 2,142,146, Jan. 3, 1939 (March 26, 1938).

Producing abrasive articles. E. S. MERRIAM. U. S. 2,141,155, Dec. 20, 1938 (April 28, 1938). A method for firing a stack of preformed green abrasive wheels containing combustible material effective on burning to fuse the contained vitrifiable bond in the wheels comprises embedding the stack of green wheels in a bed of inert granular material in a retort, initially igniting the combustible material contained in the retort charge at one end thereof, and, as the zone of burning of the combustible material in the retort charge progresses through the stack of wheels, effecting oxidation of a gaseous fuel to the rear of the advancing zone of burning of combustible material in the retort charge to preclude premature cooling of the first fired wheels in the stack.

Producing silicon or boron carbide to be used as abrasive. NORTON CO. Ger. 664,644, Aug. 18, 1938 (June 28, 1933); IV*b*/12*i*. 37. Silicon or boron carbide is produced from silicon or boron oxide and carbon in an electric resistance furnace by means of a resistance material conducting the current and located in the core of the charge. Material obtained from the zone of the reacting materials lying between the completely and incompletely transformed reacting materials of the previous charge is used as resistance. D.A.B.

Pulpstone. THURE LARSSON (Norton Co.). U. S. 2,141,608, Dec. 27, 1938 (Aug. 11, 1937).

Spindle mounting for boring, grinding, etc., machines. HEALD MACHINE CO. Brit. 497,695, Jan. 4, 1939 (May 14, 1937).

Track-grinding brick. ROBERT G. VAN KEUREN (Norton Co.). Can. 377,304, Oct. 25, 1938 (Dec. 31, 1936; in U. S., Jan. 4, 1936). G.M.H.

Valve grinder. W. R. AKANS. U. S. 2,142,595, Jan. 3, 1939 (July 8, 1938).

Valve-stem grinder. J. M. KROHN. U. S. 2,142,565, Jan. 3, 1939 (April 5, 1935).

Worm-polishing machine. J. M. RIORDAN. U. S. 2,142,415, Jan. 3, 1939 (Oct. 5, 1935).

Art and Archeology

Austrian Gothic enamels and metalwork. MARVIN CHAUNCEY ROSS. *Jour. Walters Art Gallery*, **1**, 71–83 (1938).—A detailed chronological survey of Austrian enamels in the 13th and 14th Centuries is profusely illustrated with examples at the Walters Gallery. *Cloisonné* (enameling on gold), a creation of Byzantine art of the 6th to 12th Century, was learned by European craftsmen as early as the 7th Century. By the 11th Century, a new technique was *champlevé* (enameling on copper). Nicholas of Verdun was summoned in 1181 to Klosterneuburg to decorate the churches and monastery, and 13th and 14th Century work carried on the tradition of his work. The enamels made in Vienna are very limited in their color scheme, red, blue, and turquoise being the chief colors employed. The actual enamel does not seem to be of as fine quality as that in Mosan or Limoges work. The figures are generally reserved on the copper and gilded while the background is enameled. The shadows

in the drapery are represented by deeply engraved lines which are spiked at the ends and also filled with enamel. M.E.P.

Bronze monuments of Dartmoor. J. W. BRAILSFORD. *Antiquity*, **12** [48] 454–56 (1938).—Cooking holes with pots still *in situ* were excavated. One of the pots had been broken and mended with unfired china clay. Most of the pots have round bottoms, but sherds of flat-bottomed pots were found. Much of the pottery is undatable but has points in common with bronze age forms. The makers appear to have come from Brittany or possibly from southeastern England (the latter with indirect Breton influence). A.B.S.

Ceramic sculpture. VIRGINIA WORTHINGTON. *Design*, **40** [5] 7 (1938).—W.'s experience with the behavior and limitations of clay in connection with her educational work at the Cincinnati Art Museum has evolved a sculpture medium which she finds adaptable to the expression of the unsophisticated life which she interprets and which is illustrated in the photographed group of sculptures representing amusing cowboy figures. The figures are hollowed or built hollow and grog is added to make drying and firing easier. No molds are used and these original sculptures are treated with various surface techniques including engobe, grafitto, and underglaze colors. M.E.P.

Colored barium glazes for porcelain: III. TETSUZO MURAYAMA. *Jour. Japan. Ceram. Assn.*, **45** [536] App. 55–59 (1937).—Underglaze colors are developed with barium glaze which are more brilliant than those developed with lime glaze. The coloring action of various metallic salts was investigated for a barium glaze, $0.3KNaO \cdot 0.7BaO\ 0.44Al_2O_3 \cdot 3.22SiO_2$. The colored glazes were fired to Seger cone 10 with a reducing flame. T. concludes that 2 to 4% of basic carbonate of copper produces good light reds and 1.5 to 2% of ferrous carbonate or 12 to 20% of a yellow ocher gives satisfactory celadons. **IV.** *Ibid.*, App. pp. 59–62.—Experiments were made on cone 10 copper-red glazes and the conclusions are as follows: (1) an adequate base glaze is 0.3 to $0.6KNaO \cdot 0.4$ to $0.7BaO$ 0.3 to $0.5Al_2O_3 \cdot 2.5$ to $6SiO_2$; (2) adequate amounts of basic carbonate of Cu and auxiliary tin oxide are 2 to 4% and 2 to 5%, respectively; (3) oxidizing flame is injurious; and (4) a very beautiful red is produced on colorless barium glaze if the ware is put in a porcelain vessel whose inside is coated with a copper-red glaze. S.K.

Early Derby porcelain figures. WILLIAM KING. *Arts & Dec.*, **49** [1] 14, 15, 40 (1938).—Many pieces of porcelain formerly attributed to Chelsea are now recognized as Derby. These figures were produced in the twenty-year period prior to the amalgamation with Chelsea in 1770. Derby ware can be identified in part by shrinkage of the glaze around the foot rim. Illustrated. L.F.M.

English ancient glasses. G. GWENNET. *Clarté*, **11** [9] 3–5 (1938).—G. describes several specimens of ancient glasses of great artistic and historical interest. R.W.D.

Epiktetos and his circular designs. DOROTHY KENT HILL. *Jour. Walters Art Gallery*, **1**, 24–32 (1938).—H. assigns two cups to the Epiktetan black-figured group on the basis of subject and decorative scheme because the principles of design in the round pictures of these vases are the same as those which Epiktetos painted, whether in black or in red figure. These principles of design distinguish Epiktetos from his contemporaries and connect him with an earlier painter, Tleson, who may have been his teacher. Lack of knowledge of the factory organization in the late 6th Century B.C. prevents knowing whether or not "Epiktetos design" means "Epiktetos work," but eight cups in the "bilingual" technique (535 and 530 B.C.) have recently been assigned to Epiktetos, master painter of Attic. They have internal round pictures, chiefly of animals, painted in black glaze with broad and careless incised lines for details and have external red designs of pairs of eyes, palmettes, and sometimes figures. Inside the vases, opposite each handle, are two lumps showing that the clay was still soft when the handles were attached. Illustrated. M.E.P.

***Famille Verte* vase.** *Connoisseur*, **102** [448] 331 (1938).—Full-page illustration in color of a vase of the K'ang Hsi period (1662 to 1722); the vase is decorated with four upright panels painted with rocks and flowering plants, two monsters, a phoenix, and a pheasant; it is 17 in. high. M.E.P.

Gallo-Roman potteries of Banassac, France. ANON. *Céram., Verrerie, Email.*, **6** [10] 302 (1938).—Almost a ton of unique pottery was recently discovered by C. Morel and J. Lyonnet at Banassac in Lozère, celebrated for its Gallo-Roman ceramic workshops. The pottery has a very fine body covered by a well-preserved red glaze, and much of it bears inscriptions, legends, and wishes addressed to the tribes of Gaul to whom the fired clay cups were sold. Every vase is stamped with a seal or fingerprints which identify the potters. M.V.C.

Lithium carbonate in raw alkaline glazes. FLORENCE WOOD RICHARDSON. *Jour. Amer. Ceram. Soc.*, **22** [2] 50–53 (1939).

Making of Wedgwood. FELTON WREFORD. *Pottery & Glass Record*, **20** [11] 286–88 (1938).—W. describes (1) grinding of Cornish stone and washed flint; (2) blunging of ball clay and china clay; (3) pugging of the mixture; (4) shaping, which is chiefly done by throwing and turning but also by molding; (5) decoration by applied ornaments and by painting, engraving, and printing; (6) placing or setting; (7) firing (earthenware up to 1200°C, chinaware up to 1300°C); and (8) glazing. A.B.S.

Modern pottery trade in the Aegean. S. CASSON. *Antiquity*, **12** [48] 464–73 (1938).—The economic condition of peasant and small-town life in the Aegean islands hardly differs in simplicity or complexity from what it was either in the bronze age or in the classical Greek times. A.B.S.

Pair of blanc de chine Kuan-Yins. HELEN COMSTOCK. *Connoisseur*, **102** [448] 333 (1938).—Two Kuan-Yins shown by Roland Moore are $17^1/_2$ in. high and depict the goddess on the sea with fluttering draperies and waves curling about her feet. These famous blanc de chine figures produced in the central Fukien province are of pure white paste with milk white or creamy glaze which is so fused as to seem part of the base. Illustrated. M.E.P.

Pottery in Nuzu. S. SMITH. *Antiquity*, **12** [48] 427–28 (1938).—S. gives brief notes on the pottery found at Nuzu (Mesopotamia), Brak, and Atchana. It is regarded as Khurrian and Subarean and appears to have been made in 1450 to 1500 B.C. See "Pottery—," *Ceram. Abs.*, **17** [10] 323 (1938); **18** [2] 43 (1939). A.B.S.

Quest of Helen. JOTHAM JOHNSON. *Sci. Amer.*, **159**, 189–91 (1938).—Recent excavations by the University of Cincinnati at Troy give a much more complete record. There are nine main levels with more than forty major and minor subdivisions. Comparison of the pottery at Troy with that of other nearby sites shows that Troy, level VIIa, which existed a hundred years at about 1200 B.C., was totally destroyed by fire and is the Troy of which Homer wrote. W.D.F.

Roundels of the months. *Coronet*, **5** [3] 97–102 (1938).—Twelve illustrations of circular plaques, one for each month, done in terra cotta by Luca della Robbia (1400 to 1482); each plaque has the same border in grafitto or a molded pattern, but each has a design depicting a man engaged in some agricultural activity suited to the particular month. M.E.P.

Rustic pottery from the region of Bresse and the sides of the Saône in France. G. JEANTON. *Nature* [Paris], No. 3033, pp. 161–64 (1938).—J. deals with earthenware manufactured by handicraftsmen of the country. R.W.D.

Unglazed porcelains found on the site of the Chelsea factory. BELLAMY GARDNER. *Connoisseur*, **102** [448] 315–19 (1938).—Three kilns were uncovered during the excavation of the site of the old Chelsea Factory in 1906. Biscuit pieces were found on the kiln shelves; saggers, pyramid supports, etc., were also found. None of these pieces was made later than 1758, and interesting comparisons with finished counterparts show them to be

examples from both the blue and the red anchor periods. These pieces, together with the Chelsea rate books and the annual auction catalogs, show a rather complete history of this factory, although several gaps, missing examples, and an authentic portrait of Nicholas Sprimont, are still being sought by the collectors and historians. Illustrated. M.E.P.

Where to see antique ceramics. Arles-sur-Rhône. JEAN THUILE. *Céram., Verrerie, Email.*, **6** [10] 305–16 (1938).—The 7 pieces of 16th Century Nimes faience which are kept at the hospital in Arles are described in detail. They are of the type attributed to the renowned Sigalon. The colors of the backgrounds, repeated in alternation, are water green, lemon yellow, sea blue, and mustard ocher and compose the decoration called "a quartieri" on which are acanthus friezes, scroll patterns, conventionalized foliage, and heads or busts. At the Maurel pharmacy in Arles which was founded in 1680 some of the original apothecary jars, cylindrical and rounded, with covers, and mounted on pedestals, are still preserved. There are three rows of covered labelled jars, in cases of carved wood simulating the real cases, which are copies of an original lot which still survives. They have an inscription and design which influenced the writing and decoration on other pots of pharmacies in the meridional region. Over 30 jars remain which are distinguished by a unique design drawn in camaieu blue, the inscription and its framing both being blue. A serial number is on each pedestal. The clay is light and admirably worked with a beautiful white enamel which adheres, as do the colors, without cracking or swelling. Later pieces preserved at the pharmacy are also described, and historical notes on the families of potters of Arles are given. Illustrated. See "Ancient—," *Ceram. Abs.*, **17** [10] 323 (1938). M.V.C.

PATENTS

Bottle. HERBERT LEHMANN. Can. 377,344, Oct. 25, 1938 (June 24, 1936). G.M.H.

Decalcomania paper. JOHN MACLAURIN. Can. 377,631, Nov. 8, 1938 (April 6, 1936). G.M.H.

Designs for:

Bead for bottle. J. L. MATHIEU & CIE. Can. 12,187, Dec. 2, 1938. G.M.H.

Bean pot. C. C. SOULE (Main Canned Foods, Inc.). U. S. 112,951, Jan. 17, 1939 (Dec. 1, 1938).

Bottle. ROYDEN A. BLUNT. Can. 12,164 to 12,168 and 12,172 to 12,178, Nov. 29, 1938. CHOCOLATE PRODUCTS, LTD. Can. 12,203, Dec. 7, 1938. LENTHÉRIC OF CANADA, LTD. Can. 12,149, Nov. 21, 1938. Can. 12,156, Nov. 25, 1938. WELCH GRAPE JUICE CO. Can. 12,135, Oct. 22, 1938. G.M.H.

Bottle. E. W. FUERST (Owens-Illinois Glass Co.). U. S. 112,941, Jan. 17, 1939 (Feb. 25, 1937). CLARENCE MARK (G. Washington Coffee Refining Co.). U. S. 112,703, Dec. 27, 1938 (Oct. 14, 1938). FRANK MCINTOSH. U. S. 112,782, Jan. 3, 1939 (Oct. 22, 1938). FRANK MCLAUGHLIN (Carr-Lowrey Glass Co.). U. S. 112,704, Dec. 27, 1938 (Nov. 7, 1938). FRASIER SMITH (Pennsylvania Glass Products Co.). U. S. 112,540, Dec. 13, 1938 (Oct. 19, 1938). J. F. WATSON (Borden Co.). U. S. 112,798 to 112,800, Jan. 3, 1939 (Oct. 7, 1938).

Carafe. J. R. MORGAN (Sears, Roebuck & Co.). U. S. 112,947, Jan. 17, 1939 (Oct. 17, 1938).

Chinaware. BOOTHS, LTD. Can. 12,202, Dec. 7, 1938. G.M.H.

Combined bottle and holder. LENTHÉRIC OF CANADA, LTD. Can. 12,151, Nov. 21, 1938. G.M.H.

Combined carafe and cup. J. R. MORGAN (Sears, Roebuck & Co.). U. S. 112,948, Jan. 17, 1939 (Oct. 17, 1938).

Cup. J. R. MORGAN (Sears, Roebuck & Co.). U. S. 112,949, Jan. 17, 1939 (Oct. 17, 1938).

Decanter-type bottle. LENTHÉRIC OF CANADA, LTD. Can. 12,155, Nov. 25, 1938. G.M.H.

Diffuser for electric lighting fixtures. D. L. RIPLEY (Markel Electric Products, Inc.). U. S. 112,537, Dec. 13, 1938 (April 11, 1938).

Goblet. A. J. CUNNINGHAM. U. S. 112,516 to 112,518, 112,547 to 112,551, 112,557 to 112,559, and 112,570 to 112,572, Dec. 13, 1938 (April 28, 1938). U. S. 112,853 to 112,863, Jan. 10, 1939 (April 28, 1938).

Hollow glass building block. W. D. TEAGUE (Owens-Illinois Glass Co.). U. S. 112,746, Dec. 27, 1938 (Aug. 19, 1938).

Jar. B. D. FUERST AND A. I. LORENZEN (Owens-Illinois Glass Co.). U. S. 112,940, Jan. 17, 1939 (Nov. 8, 1938). O. C. NOBLE (Tygart Valley Glass Co.). U. S. 112,783, Jan. 3, 1939 (Oct. 25, 1938). FRASIER SMITH (Hazel-Atlas Glass Co.). U. S. 112,706, Dec. 27, 1938 (Sept. 26, 1938).

Plate. HARRY BARKBY (Shenango Pottery Co.). U. S. 112,509 and 112,510, Dec. 13, 1938 (Oct. 3, 1938). YUKIO BUMA (Morimura Bros., Inc.). U. S. 112,921 to 112,932, Jan. 17, 1939 (Nov. 26, 1938). A. J. KOCH (Onondaga Pottery Co.). U. S. 112,945, Jan. 17, 1939 (Oct. 22, 1938).

Tumbler. A. J. CUNNINGHAM. U. S. 112,560, Dec. 13, 1938 (Sept. 24, 1938).

Machine for attaching decalcomania films about cylindrical objects. A. O. JOHNSON (Meyercord Co.). U. S. 2,140,186, Dec. 13, 1938 (Feb. 7, 1938).

Milk bottle. JOHN F. WATSON (Borden Co.). Can. 378,084, Dec. 6, 1938 (April 15, 1937; in U. S., April 18, 1936). G.M.H.

Cements

Fuel requirements are lower. ANON. *Concrete, Cement Mill Ed.*, **46**, 252 (1938).—In August, 1935, an average of 131.9 lb. of equivalent coal was burned per barrel of clinker. This decreased steadily to 123.0 lb. per barrel in July, 1938. This is probably due to the gradual installation over the country of better kilns, clinker coolers, and single-unit driers and pulverizers. W.D.F.

Low-heat cement. H. S. MEISSNER AND W. T. MORAN. *Eng. News-Record*, **121**, 589–93 (1938).—In large concrete masses, the heat generated by hydrating cements raises the temperature of the concrete mass considerably above that at which the concrete is placed. On cooling, cracks may develop due to high shrinkage. Cements having low-heat characteristics and other desirable properties for mass concrete construction can be produced through controlled chemical composition. Reduction in heat evolution at all ages was obtained by decreasing the tricalcium aluminate content with a consequent increase of tetracalcium alumino-ferrite. By decreasing the tricalcium silicate with a resulting increase in dicalcium silicate, a large reduction in heat hydration was obtained at early ages and a moderate reduction at later ages. At all ages up to one year, tricalcium aluminate contributed approximately twice as much heat as tricalcium silicate which produced more heat than either dicalcium silicate or tetracalcium alumino-ferrite. In low-heat cements, about $^1/_3$ less heat is generated on hydration than that ordinarily resulting from standard Portland cement; its early strength is attributed largely to the amount of tricalcium silicate present. Low-heat cements were slightly less resistant to the action of freezing and thawing but were far superior to normal cements in resistance to sulfate-bearing waters. B.C.R.

Mixed Portland cements: XVIII. SHOICHIRO NAGAI. *Jour. Japan. Ceram. Assn.*, **45** [539] 807–19 (1937).—N. studied high-silica mixed Portland cements. Test pieces of neat-cement pastes were molded and were cured in water for (*a*) 7 or (*b*) 28 days or in water for 7 days and then in warm water for (*c*) 7 or (*d*) 28 days. Contents of calcium hydroxide in hardened Portland

cements rise with time, *e.g.*, (*a*) 10.5%, (*b*) 11.2%, (*c*) 12.4%, and (*d*) 13.5%, while they decrease in blast-furnace cement and high-silica mixed Portland cements, *e.g.*, with one of the latter, (*a*) 10.5%, (*b*) 9.8%, (*c*) 8.2%, and (*d*) 5.6%. Highly siliceous admixtures seem to combine with calcium hydroxide and thereby increase long-age strength. The linear change in specimens molded from wet mortars of the mixed cements and cured in water for 3 to 364 days is, in general, smaller than that of Portland cements. Test pieces were cured in water, 10% common salt solutions, and 10% sodium sulfate solutions for 4 to 24 weeks. Those made of Portland cement and blast furnace slag cement expanded, cracked, and disintegrated in the last solution due to the formation of cement bacilli. The linear change in specimens cured in 10% common salt solutions and 10% sodium sulfate solutions is a measure of the resistivity to fresh water and sea water. High silica-mixed Portland cements resist both solutions. For Part **XIII** see *Ceram. Abs.*, **14** [9] 209 (1935). S.K.

Polynary systems with iron oxides. H. ZUR STRASSEN. *Fortschr. Mineral., Krist., & Petrog.*, **20**, 239–87 (1936).—S. discusses the system Fe–O and the polynary systems with ferrous oxide, ferric oxide, and ferric oxides of different valence in connection with their application to Portland cement without arriving at any conclusion. 65 references. E.W.S.

Volumetric determination of SO_3 in Portland cement. KOSABURO WATANABE. *Concrete, Cement Mill Ed.*, **46**, 272 (1938).—The sulfate is precipitated near boiling by crystalline barium chloride and is diluted to 200 cc. When cooled to 50°C the suspension is poured into a cylinder with a small lamp at the bottom, and the amount of solution needed to put the light out of sight is measured. This is a satisfactory method for rapid analysis. With an SO_3 content of over 2% this method gives too large an error. It works best on samples with less than 1% SO_3. W.D.F.

PATENT

Cement manufacture. C. H. BREERWOOD (Separation Process Co.). U. S. 2,144,254, Jan. 17, 1939 (Sept. 10, 1937). The method of beneficiating inferior cement raw materials of the class argillaceous limestones, marls, and chalks containing silica and a proportion of at least one silicate mineral of relatively slow settling rate in water and in excess of that desired for an ultimate cement raw material mixture comprises subjecting at least a proportion of a pulp of such a material including an abundance of slimes to froth flotation in the presence of a collecting reagent in which a fatty acid is at least an ingredient, to concentrate at least the major proportion of the weight of the free calcite, subjecting the tailings of calcite flotation to hydraulic classification to separate the excessive proportion of the silicate mineral from the remaining constituents, discarding the proportion, and combining the remaining constituents with the calcite concentrates to form at least a major proportion of the ultimate cement raw material mixture.

Enamel

Complete cleaning of sheet steel for porcelain enameling. J. J. BASCH. *Ceram. Forum*, **5** [3–4] 2, 5 (1938).—An alkaline cleaning solution properly balanced and providing an ample reserve of alkalinity, together with assisting agents possessing emulsifying, dispersing, and free rinsing properties, is necessary for complete cleaning of sheet steel for porcelain enameling. B. discusses proper design of cleaning vat, strength of solution, temperature, mechanical equipment, and general control. H.E.S.

Enamels with a low boric acid content. HEINRICH KIRST. *Glashütte*, **68** [32] 540–42 (1938).—Through the use of different raw materials or of melted silicate mixtures it is possible to produce enamels of similar composition with improved properties. A theoretical example of obtaining an enamel poor in boric acid is given. M.V.C.

Furnaces for firing enamels. A. L. *Verre & Silicates Ind.*, **9** [28–29] 327–30; [30] 341–43 (1938).—The oldest type of furnace for firing enamel is the crucible furnace which is no longer used except for special enamels in small batches, as in the manufacture of jewelry, or for small-scale tests in enamel laboratories. Shaft furnaces are still used for medium and large scale production but are rapidly being replaced by the superior revolving furnaces which are less cumbersome and can be installed where convenient; their operation and regulation are simpler and safer than those of shaft furnaces, and a homogeneous quality of frit is assured. Fusing time is reduced and production capacity is great, while operating expenses are cut down. This type of furnace lends itself to enterprises where a great number of formulas or frequent modifications of formulas are used. Two furnaces are usually installed: one for white or transparent enamels and the other for fusing masses or darker enamels. A small model exists for special enamels or laboratory tests. There are two types of revolving furnaces: (1) the furnace with horizontal "drums" of iron lined with tamped refractory clay or block, in which the fusing chamber is an elongated cylinder with conical excavations at the ends, one for the burner and the other for flue and charging; and (2) the ellipsoid furnace, which is newer than the first type and retains the advantages of the other with further improvements. The axis of rotation is oblique, and the fusing chamber is almost spherical and enveloped in a metal cylinder with a large base. The greater advantages of the elliptical form are given, and both types of furnaces are minutely described. M.V.C.

Manufacture of enamel colors and enamel. N. N. CHOLODILIN. *Zitein-Tech. So.*, Series 28, No. 2247, 9 pp. (1936); abstracted in *Referat. Silikatliteratur*, **5** [9] 5614 (1938).—For a yellow-brown color on enamel, a zinc iron spinel is used which is prepared by heating 22 ZnO, 44 iron oxide, 30 kaolin, and 4 parts nickel oxide at 900° to 1000° for 4 to 6 hr. The enamel with which the color is mixed must contain 1.5% NiO so that the spinel does not decompose. An enamel containing calcined chrome ore is used as ground enamel. A blue-green enamel color is obtained by grinding together 20 chrome oxide, 8 cobalt oxide, and 0.2 kg. clay with 16 to 20 kg. water and heating to 950° to 1000° for 24 to 36 hr. The covering power of this color is so high that a 1 to 1.5% addition suffices. The enamel should contain about 4% B_2O_3. A ground enamel containing about 15% apatite adheres well to iron with an addition of about 0.5% cobalt oxide. This enamel is more difficult to fuse than ordinary enamels and can be melted on when apatite-containing coat enamels are used. In the preparation of blue enamel on apatite ground, the mixture for enamels containing apatite is well fused with 0.18% cobalt oxide. Blue enamel is obtained by grinding the enamel with 14% clay. The enamel has a deep blue color without blue coloring material being added. The enamel is sufficiently opaque, so that the addition of zinc oxide or "leuconin" is not needed. C. prepared an apparatus for determining the adhering power of enamel which consists of two plates of iron which can be placed one on top of the other so that a space of 0.15 mm. remains between them. Supports are fastened to the backs of both plates, which can be attached to the Michaelis breaking tester. The sheets are coated with a layer of ground enamel and fired so that both sheets are cemented by a layer of enamel. In the breaking test, the adhering power is determined and calculated in kg./cm.^{2}. In a similar way, the resistance to nicking of the enamel is determined. The following values for adhering power and resistance to nicking of three different ground enamels were obtained: (1) for ground enamel with 30% borax and 0.5% cobalt oxide, resistance

to nicking on iron in kg./cm.² 8.6, adherence 5.2; (2) for ground enamel without borax and with 0.5% cobalt oxide, adherence 1.4, nicking resistance 3.8; (3) for ground enamel containing apatite, adherence 9.1, resistance to nicking 13.1 kg./cm.². M.V.C.

Principles and practice of drying enameled ware. P. G. PICKWELL. *Proc. Inst. Vitreous Enamellers*, **3**, 75–89 (1937); *Jour. Iron & Steel Inst.*, **137** [1] 28A (1938); see *Ceram. Abs.*, **17** [3] 97 (1938).

Processing of acid-resistant enamels. I. F. THOMPSON. *Ceram. Forum*, **5** [10–11] 2, 6 (1938).—Acid-resistant enamels, due to their high sodium oxide content, produce an enamel which has very poor floating properties. T. describes the use of various electrolytes such as muriatic acid, sodium aluminate, calcium chloride, ammonium alum, potassium carbonate, and ammonium carbonate in both the spraying and dipping processes. H.E.S.

Settling test *versus* screen tests for determining enamel fineness. C. THOMAS. *Ceram. Forum*, **3** [5] 6 (1937).—T. describes screen and settling tests which gave very good agreement when both were carried out with the same skill and care. H.E.S.

Sheet-steel ground-coat enamels. R. M. KING. *Proc. Inst. Vitreous Enamellers*, **3**, 203–10 (1937); *Jour. Iron & Steel Inst.*, **137** [1] 28A (1938); see *Ceram. Abs.*, **17** [5] 174 (1938).

Testing the scratching hardness of different enamels. A. KÖNIGER. *Vortrag Emaillierkurs Bergakademie Clausthal D. Bergwerksztg.*, **11**, 5 (1938); abstracted in *Referat. Silikatliteratur*, **5** [8] 5590 (1938).—K. discusses the practicability of scratching the surfaces of glass fluxes with a diamond in a certain cutting angle and of calculating the hardness of a glass flux (enamel) from the width of the crack ascertained optically. He studied the effect of the separate components on the hardness of enamels in a large number of systematically varied batches and showed the effect of metal oxides such as tin, antimony, titanium, and cerium oxides on the hardness. In batches where silicic acid is replaced by boric acid or silicic acid is replaced by cryolite, the scratching hardness changes little. Where silicic acid is replaced by potassium or sodium oxide, a definite decrease in hardness occurs with decreasing silicic acid content and increasing alkali content. A soft enamel results from the reciprocal exchange of potassium oxide toward sodium oxide. Silicic acid-alumina variations give a great increase in hardness with increasing alumina content. A fluorspar content of 9% or more causes a rapid lowering of the hardness figure. The effect of the opacifier is such that an increase in hardness is determined in the direction of tin, cerium, and titanium oxides and sodium antimonate in all tests, without regard to the different components of the batch. With tin, cerium, and titanium oxides, an increase in hardness occurs with increasing addition of opacifier; with sodium antimonate, the hardness decreases with higher antimony content. Testing the scratching hardness of a surface enamel is a quantitative measure for the evaluation of the suitability of an enamel with regard to its resistance to mechanical abrasion. M.V.C.

Glass

Causes and effects of the cooling of glass. NIUTA KLEIN. *Rev. Optique*, **16** [11] 361–85 (1937); abstracted in *Physik. Ber.*, **19** [21] 2160 (1938).—The so-called transformation period, *i.e.*, the range between the two stability states, is investigated. It is doubtful whether this range must be considered as a mixture of the two stable states in definite ratios or if it is an entirely individual state. The more slowly the glass is heated to the cooling temperature, *i.e.*, the temperature at which the glass is removed from the furnace and quickly cooled, the narrower the transformation range becomes. Experiments show that, by using a suitable cooling method, the time of cooling can be shortened considerably. Cooling methods are discussed. M.H.

Chemical compositions and water solubilities of glasses: VI. SHOICHIRO NAGAI AND SHUMPEI NAGAEDA. *Jour. Japan. Ceram. Assn.*, **45** [536] 523–34 (1937).—Experiments were made on the relation between chemical composition and durability of glass. Results of the experiment on 5 granulated samples mainly composed of 72 to 75 silica, 12 to 15 lime, and 10 to 15% soda indicate that the effect of the amount of the alkali on the durability is far greater than that of the heat treatment or acid treatment of the samples. Glass containing the most excess silica compared with Tscheuschner's formula, $z = 3(x^2 + 1)$, for soda-lime glasses, $x\mathrm{Na_2O \cdot CaO \cdot }z\mathrm{SiO_2}$, has been most durable in the powder method. Experiments were made on 5 other samples of soda-potash-lime glasses prepared from sand, sodium carbonate, calcium carbonate, and artificial feldspathic materials for the purpose of saving high-grade feldspar. The materials were prepared by heating a mixture of Zettlitz kaolin and a 30% solution of caustic potash under a pressure of 30 atm. or at a temperature of 230°C for 3 hr.; the products, hydrates of an artificial potash nephelite, were dried at 105° to 110°C to a hydrate such as $\mathrm{K_2O \cdot Al_2O_3 \cdot 2SiO_2 \cdot 0.2H_2O}$. The glasses have been distinctly improved in durability due to the introduction of potash and alumina. **VII.** *Ibid.*, [538] 693–706 (1937).—The relation between heat treatments of glasses containing alumina and magnesia and their durability was investigated. For the determination of durability, grains from 0.49 to 0.75 mm. large were treated thermally in different ways and were then heated in an autoclave under 1, 5, and 10 atm. pressure of steam. The durability of the standard soda-lime glass containing 15 soda, 13 lime, and 72% silica was improved by replacing 1 to 3% of lime by alumina. A replacement of 3 to 6% of lime by magnesia was less effective. Glasses containing 72 silica, 3 to 5 alumina, 1 to 2 magnesia, 7 to 9 lime, and 15 to 16% soda are now standard compositions of Japanese window, plate, and bottle glasses. Similar glasses prepared by the authors have proved to be very durable. For the sources of alumina and magnesia in the experiments, feldspar or alkali kaolin and dolomite or talc, respectively, were used. The percentage ratio of alkali solubility to weight decrease is discussed. The ratio was 10 to 20% for the tests under atmospheric pressure, while it varied from 30 to 35% for higher pressures. The latter values are almost equal to the percentage ratio of soda to sodium disilicate or 34%. For Part V see *Ceram. Abs.*, **17** [4] 136 (1938). S.K.

Corrosion phenomena of Corhart block in glassmelting tank furnaces. BUMPEI YOSHIKI. *Jour. Japan. Ceram. Assn.*, **45** [537] 632–45 (1937).—The high resistance of Corhart block to the corrosion of molten glass is due not only to the characteristic structure of the electrocast block but also to the special corrosion phenomena in its service. Experiments were made on the mechanism of the corrosion and its influence on glass. Results are as follows: (1) Corroded surfaces are usually covered with altered layers, and stalactitic erosion is developed on some downward surfaces of the block. (2) The corrosion takes place in 3 stages: (*a*) mullite crystals on the surface of the block dissociate due to the catalytic action of glass, and an altered zone consisting of corundum crystals and some glass matrix is formed; (*b*) a layer of viscous liquid is formed along the boundary between the corundum zone and molten glass; the liquid phase can crystallize out nephelite, $\mathrm{Na_2O \cdot Al_2O_3 \cdot 2SiO_2}$, during cooling; (*c*) the nephelite layer disappears through diffusion into the molten bath; in normal corrosion of the block, the corundum zone and the nephelite layer form a protective coating and retard the rate of corrosion. (3) If these equilibria are disturbed by internal or external causes, the rate of corrosion will be accelerated locally and an abnormal corrosion occurs. In some parts of the block facing downward, the nephelite layer and corundum zone tend to separate and fall gradually into the molten glass; conse-

quently a stalactitic corrosion is often developed. (4) The normal corrosion has no visible effect on glass, but the abnormal one sometimes causes stones in glass sheets. The stones are characterized by an enclosing nucleus of corundum, nephelite, or, rarely, carnegieite ($Na_2O \cdot Al_2O_3 \cdot 2SiO_2$) which is the high-temperature form of nephelite. Strain in the surrounding glass, however, is much weaker than that caused by grog stones and can never crack the glass sheet. S.K.

Crystalline silica in certain devitrified glasses. ARTHUR Q. TOOL AND HERBERT INSLEY. *Jour. Research Nat. Bur. Standards*, **21** [6] 743–72 (1938); R.P. 1152. Price 10¢.—Tests were made for the purpose of following, in a devitrifying glass, the well-known series of transformations—noncrystalline silica to cristobalite to tridymite to quartz—which can be completed under proper conditions at temperatures below 870°C. The devitrifying or transformation temperatures employed ranged from 625° to 950°C, and the material treated consisted of a high silica borosilicate glass which devitrified readily at temperatures above 750°C. The devitrification products were mainly studied by procuring heating and cooling curves which extended over the whole temperature range of possible rapid inversions. In addition, several of the samples were examined microscopically, and X-ray patterns were also occasionally obtained. The apparent inversion points of the cristobalite ranged from 201° to 218°C on heating and from 192° to 240°C on cooling (as indicated by the endothermic and exothermic effects). The points similarly determined for the upper inversion of the tridymite ranged from 145° to 164°C and from 127° to 155°C on heating and cooling, respectively. The corresponding points for the lower inversion of the tridymite fell between 107° and 120°C and between 82° and 101°C. The inversion points of the quartz fell between 570° and 576°C, and it appears that much of this spread can be ascribed to the relatively high rates (5°C/min.) employed in this range both on heating and cooling. The inversion effects in the upper tridymite range were usually broad and often indefinite, and they always disappeared completely soon after the effects in the lower inversion range of this material reached their maximum. Ordinarily, the interval between the complete disappearance of the effects in the upper inversion range and the full growth of those in the lower range seemed to coincide with the period within which the tridymite crystals were transformed from plates to wedge-shaped twins. The results indicate that, ultimately, wedge-shaped twins always displace the earlier formed plates as the tridymite development is advanced by increasing the duration of treatment at any reasonable temperature below a point which may greatly exceed 1000°C and that, coincidently, the inversion effects are shifted from the 150° to the 100°C range. The fact that the crystalline plates and practically all inversion effects at temperatures above the lower range were made to disappear almost completely by imposing relatively long heat treatments suggests the possibility that each of the two recognized inversion ranges of tridymite belongs to one of two low-temperature tridymite types, each of which possesses but one inversion range. It would also seem that the type inverting in the 100°C range was the stable form from 870°C to well above 1000°C at least. R.A.H.

Designing illuminated advertisements. ANON. *Glaces & Verres*, No. 56, p. 16 (1938).—A series of thirteen different glass shapes enables the reproduction of all letters of the alphabet. Made of bright flint glass, faceted, and silvered on the back, these shapes are fitted on a signboard, a show window, etc.; the least beam of light enhances their brilliancy. R.W.D.

Determining density of molten glass. A. E. BADGER AND C. G. HARMAN. *Glass Ind.*, **19** [4] 145 (1938).—The density of molten glass is determined by measuring the pressure in a bubble which is blown at the tip of a capillary tube immersed at a known depth beneath the surface of the glass. Density at room temperature is determined by hydrostatic weighing. From the thermal expansion curve of the glass as determined by the interferometer method, the change in density with temperature can be computed up to the softening temperature of the glass. The described method is not adaptable to conditions in which the glass has a somewhat high viscosity. E.J.V.

Effect of oxygen in glassmelting. Study of the melting process of technical glasses. C. KÜHL. Thesis, University of Berlin, 1937, 96 pp.; abstracted in *Referat. Silikatliteratur*, **5** [5] 5261 (1938).—K. studied the reactions which affect the liberation of oxygen, purification, and equilibria between oxides of different valence. See "Behavior—," *Ceram. Abs.*, **17** [6] 214 (1938); "Oxidation—," *ibid.*, **18** [1] 18 (1939). M.V.C.

Electrical melting of glass. Y. R. CORNELIUS. *Elektrowärme*, **8** [11] 277–82 (1938).—Based on experiments made at Niagara Falls with furnaces for melting sodium silicate, C. describes modifications on the furnaces to make glassmelting possible and economical. Single-phase furnaces are preferable to three-phase furnaces because of better space utilization; the best installation for a plant is three single-phase furnaces in order to balance the supply system. The results from this plant and another in St. Helens (England) show that a furnace with 3 zones, a top layer of the batch, a melting zone, and a refining zone below, is the best arrangement; the top layer should have a thickness of at least 370 mm. to avoid radiation losses. The cost for melting 1 ton of glass amounts to about $2.30; this varies with the cost for electrical energy. Advantages in connection with electric melting (greater cleanliness and less dust) and points to be observed when laying out a plant for it are discussed. M.H.

Expansion effects on the inversion of silica crystals in certain devitrified glasses. ARTHUR Q. TOOL AND JAMES B. SAUNDERS. *Jour. Research Nat. Bur. Standards*, **21** [6] 773–78 (1938); R.P. 1153. Price 5¢.—Expansion curves are presented which show the inversion effects of the cristobalite, tridymite, and quartz present in a devitrified glass having a relatively high silica content. These results agree in practically every respect with results presented in a previous paper ("Crystalline—," this page) and obtained from the exothermic and endothermic effects caused by the same inversions. So far as these results are concerned with the nature and changes of the inversion effects as tridymite is developed from cristobalite and quartz, they substantiate the previously suggested possibility that there are, at room temperature, two or more forms of tridymite instead of only one. R.A.H.

Glass Research Institute in Czechoslovakia. VACLAV ČTYROKÝ. *Glass Ind.*, **19** [6] 230–32 (1938).—The Glass Research Institute at Hradec Králové has technological, chemical, physical, photographic, colorimetric, and photometric laboratories and a small-scale glass plant. C. lists the equipment of the laboratories and describes the work of the Institute. See *Ceram. Abs.*, **15** [10] 297; [11] 332 (1936); "Glass—," *ibid.*, **17** [7] 244 (1938). E.J.V.

Glass sealing furnace. J. R. DILLEY. *Rev. Sci. Instruments*, **8**, 394–95 (1937).—An electric furnace used for sealing glass ends or windows to glass cylinders is described and illustrated. Construction is made so that the windows can be aligned perpendicular to the axis of the cylinder cell and also be without curvature. H.E.S.

Glasses containing iron oxide: XIV, Glasses prepared by adding alkali nitrates as oxidizing agent to batches compared with those obtained by introducing cane sugar as reducing agent to batches. KITSUZO FUWA. *Jour. Japan. Ceram. Assn.*, **45** [536] 535–42 (1937).—Glasses prepared by adding alkali nitrates to batches are compared with those obtained by introducing cane sugar to batches. If nitrates are added to batches as oxidizing agents, the percentage ratio of FeO to FeO + Fe_2O_3 in glasses is not strongly affected by the amount of the nitrates and iron oxides, whereas the ratio in glasses prepared from batches containing the reducing agent is markedly influenced by the amount of the reducing agent or the contents of iron oxides. The total transmission of the glasses is affected by the ratio as well as by the total contents of the iron oxides. The transmission of ultra-

violet rays by the glasses ranged between 274 and 346 mμ. The percentage transmission of the glasses at 700 mμ is strongly affected by the ratio. The transmission curve in the infra-red region of a glass which was prepared from a batch containing an alkali nitrate and which contains 0.077 and 0.925% ferrous and ferric oxides, respectively, is almost similar to that of another glass which was prepared by adding sugar to its batch and which contains 0.065 and 0.0915% ferrous and ferric oxides, respectively. The result indicates that the absorption of infra-red rays by glass rises in proportion to the amount of FeO in it, while it is little affected by the total amount of iron oxides, the content of ferric oxide, and the ratio of the oxides. For Part XIII see *Ceram. Abs.*, **17** [4] 138 (1938). S.K.

Grading and reclaiming grinding sand. F. G. SCHWALBE. *Glass Ind.*, **19** [6] 207–12 (1938).—Using a total of about 220 tons of sand in grinding 250,000 sq. ft. of plate glass surface every 24 hr., the Ford Motor Co. has an ingenious and unusual continuous process in which the mixture of sand and water from the grinders, at constant temperature, flows over sedimentation cones, at practically constant velocities, to be graded and classified. A debris disposal plant removes about 323 tons from the system every 24 hr. Complete technical details regarding the various steps in the process are given. Illustrated. E.J.V.

How Plexite is made and tested. ANON. *Glass Ind.*, **19** [3] 83–88 (1938).—The laminated safety glass, Plexite, produced by the American Window Glass Co., differs radically from other types, both in physical properties and the manufacturing process. Under the impact of a heavy blow the glass cracks and yields, but the sheet holds together by virtue of the rubberlike characteristic of the binder. Illustrated. E.J.V.

Hydrolytic "shell-like" defects in glass bottles. ANON. *Sprechsaal*, **71** [21] 256–57 (1938).—These defects occurring in and on glass surfaces are due to invisible injuries of the surface which are later developed and made visible by hydrolytic phenomena. They may be caused by the mechanical treatment of the bottles during use or by defective shaping. Illustrated. M.V.C.

Manufacture and post-war development of pressed glassware. D. BALMAIN. *Pottery & Glass Record*, **20** [11] 289–90 (1938).—B. describes the alleged origin of glass in Phoenicia and Egypt and the spread of its manufacture to Rome, Venice, Rhineland Bohemia, France, and England. He outlines the manufacture of pressed glass at Gateshead-on-Tyne in about 1830 and, later, elsewhere. Attempts to get away from imitating hand-cut ware are mentioned, but in England glassware of great brilliancy and showiness, imitating hand-cut ware of out-of-date patterns, sells best. A.B.S.

Melting and properties of glass in dependence on the state of raw materials and batch. A. THÜRMER AND G. GLASER. *Sprechsaal*, **71** [21] 254–56 (1938).—The grain size of the constituents of the batch is of great importance for the rate of melting. A simple soda-lime glass was used for the study. Data found for the grain size of lime and sand are given in tables. M.V.C.

Precautions in setting mural silvered plate glass. R. L. *Glaces & Verres*, No. 56, pp. 13–14 (1938).—L. presents a paper of practical interest to glaziers. R.W.D.

Properties of glasses in the system Li_2O–Na_2O–B_2O_3. N. SOLOMIN. *Zhur. Tekh. Fiz.*, **8** [6] 523–27 (1938); abstracted in *Physik. Ber.*, **19** [21] 2159 (1938).—S. investigates the thermal expansion of a series of systems of the composition Li_2O–Na_2O–B_2O_3 and establishes the diagrams expansion coefficient-composition. Replacing Na_2O by Li_2O lowers the expansion coefficient. The viscosity of the melt Li_2O–Na_2O–B_2O_3 in the softening range increases with the increase of Li_2O and Na_2O concentration. M.H.

Properties of glass stones. ANON. *Glass Ind.*, **19** [7] 272–75 (1938).—The physical characteristics, optical properties, and mode of occurrence of the common devitrification, batch, and refractory stones are presented, including quartz (SiO_2), cristobalite (SiO_2), tridymite (SiO_2), devitrite ($Na_2O \cdot 3CaO \cdot 6SiO_2$), wollastonite ($CaO \cdot SiO_2$), pseudowollastonite ($CaO \cdot SiO_2$), diopside ($CaO \cdot MgO \cdot 2SiO_2$), barium disilicate ($BaO \cdot 2SiO_2$), alamosite ($PbSiO_3$), willemite ($Zn_2SiO_4$), mullite ($3Al_2O_3 \cdot 2SiO_2$), nephelite ($Na_2O \cdot Al_2O_3 \cdot 2SiO_2$), carnegieite ($Na_2O \cdot Al_2O_3 \cdot 2SiO_2$), kyanite ($Al_2O_3 \cdot SiO_2$), sillimanite, ($Al_2O_3 \cdot SiO_2$), and corundum ($Al_2O_3$). See "Identification—," *Ceram. Abs.*, **16** [3] 87 (1937). E.J.V.

Resistance of glasses to acids and alkalis. KOZO TABATA, TATSUO YOKOYAMA, AND TAMOTSU KUSAMA. *Jour. Japan. Ceram. Assn.*, **45** [540] 897–905 (1937).—Alkali borosilicate glasses containing alumina, lime, or zinc oxide were examined, together with some commercial glasses, to determine the resistance to acids and alkalis by a powder method. Glass resists sulfuric and hydrochloric acids so well that there is scarcely a definite relation between its composition and the resistance. In regard to the resistance to the Na carbonate solution, both alumina and zinc oxide are beneficial while lime is injurious; the replacement of 0.75 mol. boric acid by 0.75 mol. lime makes the resistance considerably poor. Every oxide of Al, Ca, and Zn is advantageous for the resistance to the Na hydroxide solution. More than 0.5 mol. of boric acid must be substituted for lime. The action of the Na hydroxide solution is the most severe, and that of the Na carbonate solution is next, the two acids being the least severe. S.K.

"Rings" and floats, their manufacture and use. H. HAUSNER. *Sprechsaal*, **71** [15] 187–91; [16] 200–201 (1938).—Raw materials for rings and floats should be selected in such a way that a streakless and stoneless dissolving is assured. Acid Grossalmerode clays are preferable. The mix should be of suitable granulation and of correct composition and should be aged sufficiently long. The rings and floats should be (1) shaped in such a way as to insure long life, (2) appropriately dried, and (3) fired at the highest possible temperature in a strongly oxidizing atmosphere, but without the formation of a glaze layer; this insures longer durability. Illustrated. See "Floaters—," *Ceram. Abs.*, **16** [5] 148 (1937). M.V.C.

Spectrographic analysis permits the identification of glass vases of Middle Ages. ANON. *Céram., Verrerie, Email.*, **6** [10] 302 (1938).—During the mining of a stone quarry near Villey-Saint Étienne in Loire, France, a cemetery of the Middle Ages was found in which there were 15 vases of blown glass of beautiful line and varied form, dating from the end of the 5th Century to the beginning of the 7th Century. Tests on the composition of the glass were made at the Spectrographic Laboratory of the Institute of Optics, Paris. This is the first time that the electric arc method (voltage 100 v., intensity of 6 amp., temperature 3700°, photographs of the emission spectra of glass vapors, etc.) has been used for archeological research. The glasses of Villey were probably made in the region with natron imported from the Orient. M.V.C.

Tempering glass. V. I. VANIN. *Zhur. Tekh. Fiz.*, **8** [7] 615–20 (1938); abstracted in *Physik. Ber.*, **19** [21] 2160 (1938).—On the basis of the investigations by Gould and Hampton (*Ceram. Abs.*, **9** [10] 830 (1930)), V. derives the following formula for the cooling velocity, h, of a glass plate of thickness, a: $h = y_0/\alpha\ [2(1-\delta)\ \lambda E \times 3.5VC60]$°C/min., where y_0 = tension in the center of the glass plate, δ = Poisson's coefficient, λ = heat conductivity, E = Young's modulus, α = expansion coefficient, C = specific heat, and V = specific volume. This formula gives, as a most favorable heating of a glass plate, $h = 20/a^2$°C/min. M.H.

Term "striation" and certain other terms used in glass technology. F. W. PRESTON. *Bull. Amer. Ceram. Soc.*, **18** [1] 12–20 (1939).

Waste gas and furnace atmosphere analysis in glass-melting. ZSCHACKE. *Glashütte*, **68** [30] 503–506; [32] 537–40 (1938).—The supply of air and gas, draft, and the state and arrangement of regenerators as well as the state of the flame affect the furnace atmosphere which is decisive for melting. Its influence may equalize the effect of a temperature difference of 50° to 100°. The effect of furnace atmosphere is especially great in sulfate-contain-

ing melts where, with falling temperature and decreasing reduction, or increasing O_2 content of the atmosphere, the rate of decomposition of sulfate ($SO_3 + {}^1/_2O_2 \rightarrow SO_3$) is lowered. This control of the furnace atmosphere is important also for a suitable use of furnace gases. Z. describes an apparatus for gas analysis with the help of which waste gases may be analyzed with regard to CO_2, CO, and O_2. M.V.C.

Working of glass in tank furnaces. ANON. *Céram., Verrerie, Email.*, **6** [9] 253–56 (1938).—The effect of the tank atmosphere (whether oxidizing or reducing) on the quality of the glass is described, especially when sulfur is used as refining agent. The importance of atmospheric pressure and the analysis of flue gases are given. The construction of the tank is also described; this affects the flow of the glass which depends on the geometry of the tank and the division of temperature as well as on other variables, including the composition and color of the glass, raw materials, and moisture. M.V.C.

Zirconium oxide as a constituent of glass. ERIC PRESTON. *Foote-Prints*, **11** [2] 1–11 (1938).—In spite of the numerous oxides which have been introduced into glassmaking compositions in the past twenty years, zirconium oxide has still not been exploited as much as it deserves in view of its beneficial effects. Zircon can now be obtained which is of greater purity and uniformity than probably any other mineral now used in a glass batch. The present market price puts it approximately on a parity with alumina. Zirconia imparts greater durability to glasses, being especially valuable for resistance to boiling caustic reagents. It aids the heat-shock resisting qualities by raising the annealing temperatures, reducing thermal expansion, and increasing the work-absorbing power. [Copies of this article may be obtained free from the Foote Mineral Co., 1609 Summer St., Philadelphia, Pa.] A.P.

PATENTS

Apparatus for:

Assembling hollow building blocks. M. K. HOLMES AND DAVID JONES (Owens-Illinois Glass Co.). U. S. 2,143,696, Jan. 10, 1939 (April 19, 1937).

Cleaning sand. O. D. SISSON (Hazel-Atlas Glass Co.). U. S. 2,142,010, Dec. 27, 1938 (April 16, 1936; Oct. 8, 1936).

Feeding glass. F. L. O. WADSWORTH (Ball Brothers Co.). U. S. 2,144,470, Jan. 17, 1939 (May 22, 1934; renewed May 21, 1937).

Producing ground and polished glass strip. PILKINGTON BROS., LTD., F. B. WALDRON, AND F. E. SLOCOMBE. Brit. 497,087 and 497,088, Dec. 30, 1938 (March 10, 1937).

Producing sheet glass. J. L. DRAKE (Libbey-Owens-Ford Glass Co.). U. S. 2,140,281, Dec. 13, 1938 (May 24, 1934).

Severing molten glass. F. L. O. WADSWORTH (Ball Bros. Co.). U. S. 2,143,096, Jan. 10, 1939 (March 21, 1934; June 24, 1935; renewed Jan. 5, 1938).

Tempering glass. J. L. DRAKE (Libbey-Owens-Ford Glass Co.). U. S. 2,140,282, Dec. 13, 1938 (Dec. 26, 1935).

Articles for contacting molten glass. N. V. MIJ. TOT BEHEER EN EXPLOITATIE VAN OCTROOIEN. Brit. 496,412, Dec. 14, 1938 (June 27, 1936).

Coating with metal of glass tubes or bulbs for use in electric lamps, etc. BRITISH THOMSON-HOUSTON CO., LTD., W. J. SCOTT, AND C. J. MILNER. Brit. 496,716, Dec. 14, 1938 (May 31, 1937).

Contact lens. WILLIAM FEINBLOOM (Bausch & Lomb Optical Co.). Can. 377,675, Nov. 15, 1938 (July 26, 1937; in U. S., Aug. 22, 1936 and June 30, 1937). G.M.H.

Double sash glazing. G. B. WATKINS (Libbey-Owens-Ford Glass Co.). U. S. 2,143,747, Jan. 10, 1939 (Sept. 20, 1934).

Drawing glass tubing. W. J. WOODS (Corning Glass Works). U. S. 2,141,456, Dec. 27, 1938 (July 7, 1936).

Fiberized mineral felt. B. C. MCCLURE. U. S. 2,143,022, Jan. 10, 1939 (May 22, 1933). A felted body of fiberized mineral, the body having the inherent structural qualities of high resiliency and mass integrity under manipulation, contains as ingredients of its constituent fibers the following materials in approximately the proportions given: SiO_2 60, Al_2O_3 4, CaO 4, MgO 2, Na_2O 16, B_2O_3 4, K_2O 1.5, and PbO 8.5%.

Forehearth for molten glass. K. E. PEILER AND W. T. BARKER, JR. (Hartford-Empire Co.). U. S. 2,139,770, Dec. 13, 1938 (Sept. 24, 1935). U. S. 2,139,911, Dec. 13, 1938 (April 1, 1937).

Glass-annealing leer. CARROLL CONE (Surface Combustion Corp.). U. S. 2,140,786, Dec. 20, 1938 (March 30, 1937).

Glass article making machine. THOMAS F. PEARSON (Crown Cork & Seal Co., Inc.). Can. 378,090, Dec. 6, 1938 (Sept. 15, 1936). G.M.H.

Glass container. A. H. NICHOLSON (Federal Glass Co.). U. S. 2,141,013, Dec. 20, 1938 (June 5, 1937). A container formed of glass comprises a body portion having a removable lid resting on the upper edge thereof, the lid having its edge bevelled downwardly and outwardly with its outermost point substantially flush with the side wall of the container at its upper edge, the lid having a pair of oppositely disposed lugs integrally formed on the bevelled edge of the lid at opposite sides thereof, each of the lugs having a substantially vertically disposed outer surface which projects slightly beyond the side wall of the container at the upper edge thereof and the outermost point of the edge of the lid, the lugs being so disposed that they may be gripped by the fingers of the hand to lift the lid from the container.

Glasses transmitting infra-red radiation. GENERAL ELECTRIC CO., LTD. (Patent-Treuhand-Ges. für elektrische Glühlampen). Brit. 496,508, Dec. 14, 1938 (July 12, 1937).

Glassmelting tank. FREDERICK S. THOMPSON (Corhart Refractories Co.). Can. 377,811, Nov. 22, 1938 (Feb. 23, 1937; in U. S., March 25, 1936). G.M.H.

Glass tank skimming device. THOMAS F. PEARSON (Crown Cork & Seal Co., Inc.). Can. 378,409 to 378,411, Dec. 20, 1938 (April 28, 1937). G.M.H.

Glass-to-metal seal. VICTOR L. RONCI (Western Electric Co., Inc.). Can. 377,852, Nov. 22, 1938 (Jan. 13, 1937). G.M.H.

Glass-to-metal seal. BRITISH THOMSON-HOUSTON CO., LTD. (General Electric Co.). Brit. 497,644, Jan. 4, 1939 (May 19, 1937).

Glassware-forming machine. FRANK O'NEILL. Can. 377,492, Nov. 1, 1938 (April 22, 1936). G.M.H.

Inlaid vitreous material. FRANK SOHN (Libbey-Owens-Ford Glass Co.). U. S. 2,143,744, Jan. 10, 1939 (Jan. 21, 1935).

Lamps comprising a vitreous envelope surrounding and structurally integral with the source of light. GENERAL ELECTRIC CO., LTD. (Patent-Treuhand-Ges. für elektrische Glühlampen). Brit. 496,404, Dec. 14, 1938 (June 4, 1937).

Lens. C. V. BERGSTROM (Corning Glass Works). U. S. 2,141,159, Dec. 27, 1938 (July 10, 1933; renewed Aug. 24, 1935).

Lens edge-grinding machine. R. A. TANDY. U. S. 2,144,205, Jan. 17, 1939 (March 28, 1938).

Lens and method of manufacturing. E. H. TITMUS (Titmus Optical Co.). U. S. 2,140,410, Dec. 13, 1938 (Nov. 6, 1936).

Lens-surfacing machine. I. N. CASSITY. U. S. 2,144,179, Jan. 17, 1939 (July 12, 1937). J. J. MCCABE (Bausch & Lomb Optical Co.). U. S. 2,141,308, Dec. 27, 1938 (Nov. 5, 1936). J. J. MCCABE AND G. C. SCHELLING (Bausch & Lomb Optical Co.). U. S. 2,141,309, Dec. 27, 1938 (Jan. 11, 1937).

Loading device for glass-annealing furnace. UNITED GLASS BOTTLE MANUFACTURERS, LTD. Ger. 664,603, Aug. 18, 1938 (May 27, 1935); VI/32*a*. 34. A loading device for a glass-annealing furnace which is operated in conjunction with a molding machine is described. Glass articles are lifted from the molding machine into a chute inclined downward to a revolving part or table at the

entrance end of the feeder leading to the annealing furnace, and the device is provided with a projection or pushing attachment for stopping the movement of the articles down the chute when the lifting device is not in a capacity to take on articles. The lifting device and the projecting or pushing attachment are operated by regulators which are arranged with the revolving part or table. D.A.B.

Making fibers from glass, etc. A. E. EDWARDS (N. V. Mij. tot Beheer en Exploitatie van Octrooien). Brit. 497,714, Jan. 4, 1939 (June 22, 1937).

Manufacture of tubing of glass, etc. GENERAL ELECTRIC CO., LTD. (Patent-Treuhand-Ges. für elektrische Glühlampen). Brit. 496,405, Dec. 14, 1938 (June 4, 1937).

Manufacturing laminated glass. KODAK, LTD. Brit. 495,786, Nov. 30, 1938 (May 16, 1936).

Means for thermally toughening glass. JAMES BAILEY (Bailey & Sharp Co., Inc.). U. S. 2,144,320, Jan. 17, 1939 (Feb. 25, 1936).

Metal and glass sealing apparatus. JOHN F. DONOVAN AND FRANK J. MALLOY (Canadian General Electric Co., Ltd.). Can. 375,761, Aug. 16, 1938 (May 27, 1936). G.M.H.

Method and apparatus for feeding molten glass. F. L. O. WADSWORTH (Ball Bros. Co.). U. S. 2,141,425, Dec. 27, 1938 (March 21, 1934).

Method and apparatus for forming hollow glass articles. G. E. ROWE (Hartford-Empire Co.). U. S. 2,142,954, Jan. 3, 1939 (April 18, 1936).

Method and apparatus for the manufacture of cellular glass. ROGER LAMBERT (Soc. Anon. des Manufactures des Glaces & Produits Chimiques de St. Gobain, Chauny & Cirey). U. S. 2,143,951, Jan. 17, 1939 (Jan. 24, 1935).

Method and apparatus for shaping hollow glass articles. F. B. DEHN (G. M. S. Corp.). Brit. 497,177, Dec. 30, 1938 (Jan. 7, 1938).

Method and apparatus for tempering glass. SOC. ASSUREX LE ROI DES VERRES DE SÉCURITÉ MAGNIEN, MONNIER & CIE AND LÉON PETIT. Ger. 664,826, Aug. 18, 1938 (Jan. 15, 1935); VI/32*a*. 30. A method is given for tempering plates of mirror glass, etc., by means of air currents; the nozzles are arranged at equal intervals. The nozzles and the glass plates are moved uninterruptedly in closed curves in planes during the tempering process. The air nozzles are arranged and they and/or the glass plates are shifted in such a manner that the nozzle paths consisting of straight or evenly curved stretches are distributed on the plate in equilateral triangular surfaces whose sides, being formed by the straight stretches or by the chords of the curved stretches, are equal to the intervals of the nozzles. D.A.B.

Nonfogging laminated glass. W. O. HERRMANN AND ALFONS VON PUTZER-REYBEGG (Chemische Forschungsges. m.b.H.). U. S. 2,143,482, Jan. 10, 1939 (May 13, 1936).

Nonrefillable bottle. ARTHUR PATTERSON. Can. 377,493, Nov. 1, 1938 (April 21, 1937). G.M.H.

Nonspill liquid cocktail drinking glass. JOLL PERRY. U. S. 2,143,027, Jan. 10, 1939 (Aug. 20, 1935).

Optical lens. DONALD J. LODER (Canadian Industries, Ltd.). Can. 377,393 and 377,394, Nov. 1, 1938 (Nov. 19, 1935). G.M.H.

Packing means for hollow ware. C. K. LAVERE (Anchor Hocking Glass Corp.). U. S. 2,142,518, Jan. 3, 1939 (May 13, 1938).

Preparation of silica for glass batches. CORNING GLASS WORKS AND R. HADDAN. Brit. 497,171, Dec. 30, 1938 (Dec. 1, 1937); addition to 462,213, March 17, 1937.

Process and apparatus for forming hollow glass articles. G. E. ROWE (Hartford-Empire Co.). U. S. 2,142,955, Jan. 3, 1939 (Dec. 1, 1937).

Process and apparatus for making uniform the temperature within a mass of glass or analogous vitreous material fused by dielectric losses in the mass. M. DESCARSIN. Brit. 495,534, Nov. 30, 1938 (Feb. 19, 1937); addition to 475,014, Nov. 24, 1937.

Process for the manufacture of tubular glass bodies. M. SAMUEL. Brit. 497,486, Jan. 4, 1939 (June 18, 1937).

Producing graduated plates. PAUL HEINISCH, ASKANIA-WERKE, A.-G. (Centralwerkstatt Dessau), AND CARL BAMBERG-FRIEDENAU. Ger. 665,518, Sept. 8, 1938 (Nov. 16, 1936); VI/32*b*. 10; addition to Ger. 662,741 (*Ceram. Abs.*, **18** [1] 21 (1939)). The marking or graduation is applied to the glass as stated in Ger. 662,741, and the graduated plate is further treated in an intensifying and/or tinting bath(s). D.A.B.

Production of colored glass articles, especially glass plates. P. VIRET. Swiss 198,653, Aug. 5, 1937; *Chem.-Ztg.*, **62** [96] 865 (1938). D.A.B.

Production of glass fibers or filaments. SOC. ANON. DES MANUFACTURES DES GLACES & PRODUITS CHIMIQUES DE ST. GOBAIN, CHAUNY & CIREY. Fr. 832,509, May 13, 1937; *Chem.-Ztg.*, **62** [89] 806 (1938). D.A.B.

Receptacle for containing glass during its manufacture. J. H. PARTRIDGE (General Electric Co.). U. S. 2,141,930, Dec. 27, 1938 (May 11, 1936).

Safety glass. H. E. POTTS AND CARBIDE & CARBON CHEMICALS CORP. Brit. 497,642, Jan. 4, 1939 (April 22, 1937); addition to Brit. 460,230, Feb. 3, 1937.

Sealing metallic bodies hermetically through vitreous walls. GENERAL ELECTRIC CO., LTD. (Patent-Treuhand-Ges. für elektrische Glühlampen). Brit. 496,679, Dec. 14, 1938 (June 14, 1937).

Silica preparation for glass batches. HARRISON P. HOOD (Corning Glass Works). Can. 378,387, Dec. 20, 1938 (March 14, 1936). G.M.H.

Splinterless glass. GEORG KRÄNZLEIN (I. G. Farbenindustrie A.-G.). U. S. 2,144,067, Jan. 17, 1939 (Dec. 17, 1934).

Strengthening glass. C. J. PHILLIPS (Corning Glass Works). U. S. 2,143,796, Jan. 10, 1939 (July 30, 1937); continuation of application Serial No. 6094, Feb. 11, 1935. The method for improving the strength of glass articles includes fortifying the article and then immediately tempering it.

Tempering glass articles. CORNING GLASS WORKS. Ger. 664,602, Aug. 18, 1938 (April 17, 1936); VI/32*a*. 30. The glass article is heated to a temperature which is near the limit of expansion and is then brought to a temperature lying near or above the softening point of the glass by a further short and strong heating of only the outer surface of the glass article; the article is then cooled or annealed in the usual manner. D.A.B.

Tempering glass plates or sheets. A. A. THORNTON (Neue Glasindustrie-Ges.). Brit. 496,434, Dec. 14, 1938 (Jan. 5, 1938).

Timing system for glass feeders. H. P. SCHAFFER AND D. O. HEADLEY (Hazel-Atlas Glass Co.). U. S. 2,142,006, Dec. 27, 1938 (Dec. 15, 1936).

Structural Clay Products

Brick, material for "autarchy" in construction. ALDO ALETTI. *Ceram. & Laterizi*, **1938**, Jan.–April, pp. 8–11.—New and original effects combining brick with stone and marble in the construction of public buildings in Italy are illustrated. M.V.C.

Damp-tight brickwork. LEONARD W. BURRIDGE. *Trans. Ceram. Soc.*, **37** [10] 443–79 (1938); see *Ceram. Abs.*, **18** [1] 22 (1939). R.A.H.

Reinforced brick pavements. H. Z. SCHOFIELD. *Bull. Amer. Ceram. Soc.*, **18** [1] 20–21 (1939).

PATENTS

Brick-bond gage. JOSEPH PALMER. U. S. 2,140,714, Dec. 20, 1938 (May 29, 1937).

Building block. E. R. HARRAP. U. S. 2,140,226, Dec. 13, 1938 (Feb. 4, 1937). A generally rectangular

block for wall construction comprises a substantially rigid impermeable sheet of plastic insulating material bent back and forth to provide a plurality of dovetailing loops adapted to extend vertically when the block is positioned and a porous mineral facing permanently keyed to the dovetailing loops.

Building construction. F. D. LIVERMORE (V. J. Miller). U. S. 2,143,420, Jan. 10, 1939 (June 24, 1936). A building wall structure is composed of tile laid in rows, the inner side of the tile having grooves extending along the tile, and slots extending from the inner faces of the tile to the grooves and being of narrower width than the grooves, a furring strip having a slot extending inwardly from one of its edges, and a wedge member engaging in the slot of the furring strip, the furring strip and wedge being driven through the slot in the tile and into the groove in the tile in a direction laterally of the plane of the tile whereby the furring strip is forced over the wedge while the wedge abuts against the bottom of the slots in the tile to cause the spreading of the furring strip to prevent its withdrawal from the slot.

Composition for treating natural sandstone, brickwork, etc. W. ANDERSON. Brit. 497,522, Jan. 4, 1939 (March 5, 1938).

Machine for ornamenting brick. L. BENTLEY AND E. GARFORTH. Brit. 497,386, Dec. 30, 1938 (Sept. 28, 1937).

Machine for roughening the surface of brick, building blocks, etc. R. T. L. SHORROCK. Brit. 497,483, Jan. 4, 1939 (June 15, 1937).

Refractories

Absorption of magnesia by chromite spinel. L. J. TROSTEL. *Jour. Amer. Ceram. Soc.*, **22** [2] 46–50 (1939).

Acid-lined arc furnaces for the production of steel castings. R. VAN TONGEL, SR. *Stahl & Eisen*, **58**, 83 (1938).—Acid-lined electric arc furnaces offer advantages where soft steel of a low phosphorus and sulfur content (0.03% each) is required in relatively small quantities. The steel can be superheated, is readily castable into small shapes, is deoxidized throughout, and the danger of casting cracks is small. The lining is more durable and the cost of the steel less than that in a basic-lined arc furnace. L.R.B.

Attempts to produce lightweight refractory concrete for suspended furnace roofs. S. V. GLEBOV AND E. A. GERMAN. *Ogneupory*, **5** [9] 615–18 (1937).—The basic materials of lightweight refractory concrete are refractory cement and lightweight grog. M.V.C.

Behavior of refractory clays at high temperatures. V. V. GONCHAROV. *Ogneupory*, **5** [10] 720–25 (1937).—G. studied changes in the mineralogical composition of refractory clays fired at 1000° to 1600°C. Mullite is the basic crystalline phase of clays fired at 1000° to 1600°; at 1100° mullite is present as thin crystals. At higher temperatures, these crystals of mullite grow in size. M.V.C.

Choice of a method of dehydration of refractory clays. S. V. GLEBOV. *Ogneupory*, **5** [8] 527–29 (1937).—Experiments show that heating refractory clays for 60 min. at 550° to 600°C to dehydrate them is insufficient. According to G., the most suitable apparatus for dehydrating is the agglomeration grate of Dwight-Lloyd. M.V.C.

Chrome refractories for use in the neutral course of the basic open-hearth furnace. T. R. LYNAM AND W. J. REES. *Trans. Ceram. Soc.*, **37** [11] 481–505 (1938).—The mechanical strength at high temperatures of fired test pieces prepared from a chrome batch containing magnesia added as pure MgO in the proportion calculated to convert the serpentine present to forsterite was little greater than that obtained with the use of a normal chrome batch. Gradual increase in the proportion of the magnesia added was accomplished by gradual increase in forsterite development with consequent increase in mechanical strength at high temperatures. More obvious improvements were obtained with the use of calcined Grecian magnesite instead of pure MgO, probably due to (1) the presence of small proportions of ferruginous impurities, facilitating reaction with the serpentine, or (2) a small proportion of forsterite, developed during calcination, contained in the Grecian magnesite. A product prepared from a lime-bonded chrome concentrate batch showed no marked improvement in mechanical strength at high temperatures over one prepared from the concentrate batch alone. A product prepared from a lime-bonded Rhodesian chrome batch possessed an even lower mechanical strength at high temperatures than that of one prepared from the Rhodesian chrome batch alone. Results obtained using barium sulfate as a bond for chrome batches indicate that it helps to bring about a marked improvement in mechanical strength at high temperatures. Experiments using the batches prepared from precalcined chrome ore show that a higher mechanical strength at high temperatures can be obtained by the use of a barium sulfate-bonded chrome batch (using precalcined Grecian ore of normal grade) than by the use of a batch prepared from precalcined Turkish ore of high grade, either alone or bonded with barium sulfate, as the barium sulfate reacts with the residual low-temperature melt present in the calcined Grecian ore, whereas the small proportion of low-temperature melt in the Turkish ore is used up by reaction during calcination, thus leaving no residual melt for reaction with the added barium sulfate. In most cases, the lowest porosity and the highest bulk-density figures were obtained on test pieces made by the hand-tamping process as used for the manufacture of basic and neutral refractories. The range of best grading compositions from the point of view of low porosity and high bulk density encloses the 45 coarse, 10 medium, and 45% fine composition. The slag-test crucibles prepared from the grading compositions giving the lowest porosity figures and highest bulk-density values offered the greatest resistance to slag absorption, whereas those having high porosities absorbed the slag and eventually lost shape by bloating. The sound briquettes were subjected to a simple spalling test. This test, together with the application of a slight tensional force after test, indicates that, although the briquettes prepared from the more coarse grading compositions offer very good resistance to spalling, they have become weak structurally and are also exceptionally friable. The improvement in mechanical strength at high temperatures expected from test pieces prepared from the grading compositions giving the lowest porosity and highest bulk-density values was not realized, due to the absence of bond and to the low forming pressure. R.A.H.

Course in glassmaking. ANON. *Verre & Silicates Ind.*, **9** [31] 358–60 (1938).—Tests according to Partridge on the texture, crystalline structure, density, resistance under load at high temperature, expansion, and resistance to corrosion of refractory products are described. These tests are very instructive as they submit block to conditions similar to those in normal service and permit comparison of block of different quality and production. See *Ceram. Abs.*, **18** [1] 23 (1939). M.V.C.

Determination of the resistance of silica brick to slag. F. D. STAROSTIN. *Ogneupory*, **5** [9] 678–84 (1937).—The method is based on the heating of the silica brick sample with the slag in an electric kiln and the determination of the volume of the sample. Slag resistance depends on the structure of the body. With increased density and increased grain size, silica brick becomes more slag resistant. This method may also be used for determining the stability of grog products. M.V.C.

Distribution of porosity in silica brick molded with the Wolf-Buckau press. L. M. ZIL'BERFARB AND T. V. MEMNONOVA. *Ogneupory*, **5** [8] 524–27 (1937).—The density and porosity of Dinas brick shaped in Wolf-Buckau presses are nonuniform, varying 4 and 5%. This

nonuniform distribution of pores is accounted for by the construction of the press. Porosity has no effect on the mineralogical composition of silica brick. M.V.C.

Effects of expansion in a coke-oven battery. C. PETIT. *Rev. Univ. Mines*, [8] **12** [10] 409–14 (1936).—Because of the price of highly refractory material in Europe, only the carbonization chamber and the whole part of the oven directly connected with the combustion are made of such material, while the lower part is made of fire brick (chamotte). To avoid the danger of dislocation of the brickwork when the oven is started, the Société Copper has perfected a patented anchorage system which holds together the parts of the structure built of different material until about 600°C has been reached, when the danger of them coming apart is over. E.W.S.

Electrocorundum linings for furnaces used in the ceramic industry. H. WINKELMAN. *Sprechsaal*, **71** [21] 253–54 (1938).—Protective coats greatly increase the life of refractory walls. These linings are generally composed of a material containing SiC. Mixes containing 75% SiC and 25% clay or 75% SiC and 25% siliceous water glass diluted with a little water are applied on the dry clean refractory walls in a uniform thin layer. After 24 hours' drying, the furnace may be heated. M.V.C.

Influence of firing temperature and grain size on the gas permeability of refractory brick. ANTON KANZ. *Arch. Eisenhüttenwesen*, **12** [5] 247–51 (1938).—Commercial magnesite, silica, and fire brick were fired a different number of times or fired at different temperatures. Their gas permeability increases with greater firing temperature up to the sintering point when it drops rapidly. In the case of fire brick, the continuous increase of permeability is interrupted at 1300°C, after which the normal increase follows. Larger grain size leads to greater gas permeability and is not affected by the firing temperature. J.D.G.

Load-bearing power of siliceous refractories. SEIJI KONDO AND YASUSHI INAMURA. *Jour. Japan. Ceram. Assn.*, **45** [539] 789–99 (1937).—The softening behavior of siliceous refractories under a load of 2 kg./sq. cm. was examined with the following results: (1) The softening temperature of semisilica brick rises with increasing contents of silica. An increase of silica causes an increase of thermal expansion but it serves in reducing residual contraction. (2) Silica brick made of different quartzites softens at temperatures varying from about 1500° to 1600°C. Those rich in silica do not always have high softening temperatures. (3) The influence of the fineness of quartzite grain upon the softening temperature is not intense except when the grain is very fine, *e.g.*, mean diameter 0.25 mm. (4) The softening temperature of silica brick made solely of quartzite is strikingly higher than that of a lime-bonded brick. There is no remarkable difference, however, in the softening temperatures of the brick containing 1 to 4% of lime, *e.g.*, 1585° to 1572°. (5) Forming pressures over 150 kg./sq. cm. only slightly improve the softening behavior and other physical properties. Probably the most economical pressure for commercial products is 150 kg./sq. cm. S.K.

Load test of highly aluminous refractories. TAKEHIKO UKISU AND SHIGEKI MIZUNO. *Jour. Japan. Ceram. Assn.*, **45** [538] 730–37 (1937).—Experiments were made on the load-bearing property of highly aluminous refractories at high temperatures. The highly aluminous refractories are those made of materials containing over 39.6% of alumina or richer in alumina than kaolinite. Diaspores of Tajima and Mitsuishi poor in ferric oxide, diaspore clays of Fukushu in Manchuria and Sekimonsai in North China containing diaspore, kaolinite, and much ferric oxide, and Indian kyanite were used. They were calcined at Seger cone 18 and then ground. A small amount of Kibushi, a ball clay, was added. Test pieces were fired to cone 18. The softening temperatures of home materials were far higher than those of materials from Manchuria and China. The latter materials seem to stand thermal shock better. Kyanite dissociates, on heating, into mullite, corundum, and cristobalite or tridymite. High expansion of the silica tends to elevate the softening temperature of kyanite. Ferric oxide is injurious. The softening temperature has proportional relation to linear expansion within a certain range. S.K.

Operation of coke oven gas fired open-hearth furnaces with powdered lignite additions. C. KREUTZER. *Stahl & Eisen*, **57**, 1397 (1937).—The regenerator chambers employed in conjunction with coke oven gas fired open-hearth furnaces, where additions of pulverized lignite had been made to the fuel, formerly failed by choking up due to the narrow cross section of the gas passages. Consequently, there was an excessive consumption of brick and an increase in the fuel and repair bills. By reducing the amount of brickwork in the lower part of the regenerator, the dust and slag particles can fall through. It is advantageous to employ high alumina brick (greater than 50% alumina) which are resistant to flying slag; the slag can be run off in a molten state from the brick in an emergency. One of the advantages of this method of construction is the higher rate of heating. Loss by erosion is negligible during the whole life of the brick. L.R.B.

Production and testing of refractory putties in boiler furnaces. S. V. GLEBOV AND A. K. UVAROV. *Ogneupory*, **5** [10] 697–705 (1937).—The composition and characteristics of various refractory putties and brick for boiler furnaces are given in tables. M.V.C.

Refractories and thermal shock. J. F. HYSLOP. *Brit. Clayworker*, **47** [560] 282–84 (1938).—H. gives the main factors involved in the resistance of refractories to thermal shock and emphasizes the strength characteristics. Several experiments were made with two abnormal fire brick. The two brick were given similar thermal shocks. In one case the nature of the fractures was tangential or shearing, the brick losing corners, ends, or edges, with no sign of decided tensile cracks. In the second example, the type of fracture was tensile, the brick developing cracks normal to the surface without showing any marked sign of losing corners, ends, or edges. This dissimilar behavior when subjected to similar thermal shock is explained by the fact that one brick had low resistance to tangential but high resistance to normal stresses, whereas the other brick had low resistance to normal but high resistance to tangential stresses. This means that the nature of the resistance of a refractory to thermal shock depends upon both its tensile and shear characteristics. High resistance to the one type of stress does not necessarily indicate high resistance to the other. The ideal thermal shock body would have high resistance for both normal and tangential stresses. This view explains a number of anomalies between laboratory testing and service behavior. R.A.H.

Refractoriness under load of chrome-magnesite brick. A. E. DODD. *Trans. Ceram. Soc.*, **37** [10] 436–42 (1938); see *Ceram. Abs.*, **17** [4] 144 (1938). R.A.H.

Refractory cements. N. I. VORONIN. *Ogneupory*, **5** [11] 790–97; [12] 863–70 (1937).—V. studied chromite, andalusite, and grog putties with a ceramic and organic bond. These putties are used for protecting lightweight and normal grog brick. Chromite cements can not be used for protecting lightweight refractories; they should be used when refractories are strongly corroded by slag. Andalusite and grog cement should be used when severe temperature fluctuations prevail. M.V.C.

Refractory cements and mortars: III. SHOICHIRO NAGAI AND JUNZO KATAYAMA. *Jour. Japan. Ceram. Assn.*, **45** [535] 447–58 (1937).—Tests were made on refractory cements on the market and on the preparation of hydraulic refractory cements. The P.C.E. of 6 cements on the market ranged from Seger cone 31 to 32 for a highly aluminous cement to cone 8 to 9 for a cement rich in silica and poor in alumina. The former was the weakest on hardening. The corrosion of the cements by a blast-furnace slag, a coal ash, a copper refinery slag, and a window glass was compared by determining the P.C.E. values of mixtures of 90 to 70 parts of the cements and 10 to 30 parts of the latter. The P.C.E. values of the cements were lowered a great deal by an introduc-

tion of only 10% of the slags. Highly aluminous cements were the most refractory, although their P.C.E. values were lowered the most severely. The authors prepared new refractory cements of the following 3 elements: (1) the refractory element, a ground diaspore clay or a powder of electrically molten mass of highly aluminous clays, mainly composed of mullite and corundum; (2) the hardening element, a pulverized artificial calcium aluminate, $CaO \cdot Al_2O_3$ or $3CaO \cdot 5Al_2O_3$; and (3) the plastic element, pulverized bentonite, talc, etc. These elements were mixed in weight proportions of 70–90:30–10:0 or 80:15–18:5–2. The cements showed good hydraulic property or hardened quickly and strongly at ordinary temperatures. The new cements were examined for specific gravity, fineness, chemical composition, loss and shrinkage in drying and firing, compressive strength on hardening and firing, and softening behavior under load. For Part II see *Ceram. Abs.*, **17** [4] 132 (1938). S.K.

Refractory linings of rotary kilns for firing aluminum hydroxide. I. I. KUZMENKO. *Ogneupory*, **5** [11] 809–12 (1937).—On the basis of studies made of the operation of rotary kilns used for calcining aluminum hydroxide at the Dnieper aluminum plant, K. recommends the use of grog brick containing 96% grog with a maximum grain size of 10 mm. See "Preliminary—," *Ceram. Abs.*, **17** [2] 73 (1938). M.V.C.

Refractory putty for covers of electrical kilns for heat-treating steel bands. R. T. MAKHL. *Ogneupory*, **5** [7] 461–63 (1937).—On the basis of a study of imported refractory putty for covers of electrical kilns for heat-treating steel bands, a series of compositions of similar putty was developed from native raw materials in Russia. Tables show the composition of these putties. M.V.C.

Relationship between the composition and refractoriness under load of commercial chrome-magnesite brick. A. E. DODD. *Trans. Ceram. Soc.*, **37** [10] 427–35 (1938). —Results obtained on a large number of commercial chrome-magnesite brick show that there is a general relation between the composition and the refractoriness under load; for maximum high-temperature strength the alumina content must not exceed about 8%, and the chromic oxide and magnesia should be present in approximately equal proportions, the exact relation being shown in a triaxial diagram. Variations of 3 to 9% in the silica content and of 10 to 20% in the iron oxide content appear to have very little effect on the refractoriness under load, and magnesia can be partially replaced by lime without materially affecting this property. R.A.H.

Reversible thermal expansion of refractory materials. G. R. RIGBY AND A. T. GREEN. *Trans. Ceram. Soc.*, **37** [9] 355–403 (1938).—The thermal expansion of refractory materials and the relation of thermal spalling to this property are reviewed. R.A.H.

Rotary-kiln ring in theory and practice. TOYOFUJI-MARU YOSHII. *Jour. Japan. Ceram. Assn.*, **45** [538] 724–29 (1937).—Berlek and Litinsky recommended magnesia brick for the lining of rotary kilns. Kremmer suggested an admixture of lime to coal. Y. concludes that (1) the melting point of coal ash should be higher than Seger cone 4*a*; lime lowers the melting point and is therefore injurious; (2) an increase of kiln diameter is advantageous; (3) the distant or soft ring is far insensitive to thermal shock and does not fall off the lining easily; (4) if the residual lime-silica modulus, *i.e.*, molar ratio of total lime minus lime for $CaO \cdot Al_2O_3$ to total silica, is smaller than a definite value, the ring does not adhere to the lining; and (5) the thermal expansion of magnesia brick is nearly the same as that of the kiln coating up to about 900°C. Magnesia brick may therefore be recommended for the clinkering zone. See "Annular—," *Ceram. Abs.*, **16** [4] 109 (1937). S.K.

Shrinkage of magnesia which takes place in its dead-burning. SEIJI KONDO AND HIROSHI YOSHIDA. *Jour. Japan. Ceram. Assn.*, **45** [538] 707–16 (1937).—Thermal dissociation of magnesite of Byakkozan in South Manchuria begins at about 400°C and is nearly completed at 620°. Diffraction patterns of the magnesite fired to temperatures ranging from 600° to 1800° are exactly the same. Magnesite produces periclase as soon as it dissociates. The rate of shrinkage of test pieces made of C.P. magnesia rises suddenly at about 1290° and attains its maximum value at 1385°, arriving at a nearly constant value at 1670°. SiO_2, Al_2O_3, Fe_2O_3, Cr_2O_3, and Mn_2O_3 accelerate the shrinkage, although the effect is not so intense as that for natural magnesite. The rate rises again at about 1470° and 1450° with Al_2O_3 and Cr_2O_3, respectively. The other fluxes show less distinct secondary shrinkages. The effect of FeS_2 and $PbSO_4$ is not so intense as expected. A test piece with 2% NaCl begins to shrink at about 600° and completes the first shrinkage at a temperature for the maximum rate being lowered by about 150°. The effect of barium fluoride is also considerable, though weaker than that of calcium fluoride. S.K.

Silica refractories for cupola service. W. J. REES. *Refrac. Jour.*, **14** [9] 491–500 (1938).—In general, cupola linings are composed of either fire brick, brick or blocks cut to shape from a natural siliceous rock or "firestone," or plastic or semiplastic ramming material. The high spalling tendency of silica brick has eliminated its use, but by substituting a clay bond for the usual lime bond, thus decidedly reducing its tendency to spall, silica brick should give good service. Silica brick made from quartzites containing 1 to 3% finely dispersed TiO_2 have a much higher spalling resistance than brick made from normal quartzites. Ramming mixtures are usually highly siliceous, being composed of either a natural siliceous clay containing sufficient clay for plasticity or crushed ganister ground with plastic fire clay. In either case, close control of grinding is essential to obtain a closely packed lining. To accomplish this, the amount of intermediate sized particles should be kept at a minimum and the proportion of coarse and fine particles about equal. B.C.R.

Silica refractories: their production and properties. W. J. REES. *Year Book Coke Oven Managers' Assn.*, **1938**, pp. 193–207; *Jour. Iron & Steel Inst.*, **137** [1] 171A (1938); see *Ceram. Abs.*, **16** [7] 208 (1937).

Soda-ash foundry-slag attack on the refractory lining of a teapot-type reservoir ladle. PAUL S. DEAR. *Bull. Amer. Ceram. Soc.*, **18** [1] 4–8 (1939).

Special refractories for rotary cement kilns. R. R. MATVEEV AND A. S. KASHA. *Ogneupory*, **5** [11] 798–808 (1937).—Unfired chromite refractories are the most suitable for rotary cement kilns. M.V.C.

Spottiness of silica brick. T. V. MEMNONOVA AND L. M. ZIL'BERFARB. *Ogneupory*, **5** [9] 613–15 (1937).—Microscopic study showed that spots in silica products are caused by the presence of pseudowollastonite and calcium ferrite. A high content of these minerals in silica brick lowers the values of some of their ceramic properties. M.V.C.

Use of barium compounds in the production of refractories. R. MATVEEV. *Ogneupory*, **5** [10] 684–97 (1937).—Experiments show that barium compounds may be used as admixtures for ceramic bodies as they improve the quality of such bodies; they may also be used as special products (from barium aluminosilicates) or as refractory binding agents. The compound $2SiO_2 \cdot Al_2O_3 \cdot BaO$ has a higher refractoriness (1780°C). BaO markedly lowers the coefficient of thermal expansion of refractory bodies and hence increases their thermal stability. M.V.C.

Use of carbon dioxide in treating raw magnesite brick. V. BELOVODSKIĬ, L. KOTCHENKO, AND L. BUBNOVA. *Ogneupory*, **5** [7] 471–76 (1937).—It is possible to manufacture refractory products by treating the raw products with carbon dioxide instead of drying. M.V.C.

Use of soda in blast furnaces of the Rochling Iron and Steel Works. A. HOLSCHUH. *Stahl & Eisen*, **58**, 133 (1938).—The desulfurization of low-manganese basic Bessemer iron at the Rochling Works is done with the help of soda melted in a rotary smelter of $2^1/_2$ tons capacity, lined with refractory material. After testing

fire clay, magnesite, and sillimanite, a magnesite brick lining, backed with insulation, was tried with some success. After 200 tons of soda had been melted in 5 weeks, however, the brickwork of the conical mouths came away. This was in part due to attack of the insulation by the liquid soda via the joints, in consequence of which the magnesite brick fell out. Consequently, monolithic dolomite rammed linings were employed; these are somewhat leaner and more finely ground than ordinary tar dolomite for basic Bessemer converters. One end of the smelter is detachable because the ramming can not be done through the 30 cm. diameter mouths. The dolomite is fired on. Six-hundred tons of soda were melted in a lining of this kind at the rate of 15 tons a day. Concrete such as is used to line cement kilns and ground bituminous shale have both given serviceable results. L.R.B.

X-ray study of aluminosilicate refractories. A. H. JAY. *Brit. Clayworker*, **47** [560] 276–78 (1938).—J. studied the constitution of fired clay products as used in steelworks by X-ray methods of analysis. The constitution is expressed by the relative amounts of residual quartz, alumina, cristobalite, and mullite. Fundamental information regarding the crystalline changes occurring during firing was obtained from laboratory and commercially fired clays. From this information, J. found that it is possible to estimate the firing temperature (between 1000° and 1300°C) of commercially fired products. R.A.H.

SEPARATE PUBLICATION

Refractory lining for cupola furnaces. H. FRINGS. Herman Frings & Co., Industriesandwerk. St. Pölten, Lower Austria, 1937. 31 pp. Reviewed in *Referat. Silikatliteratur*, **4** [6] 4053 (1937).—F. deals with the use of Fricosal, a refractory lining used in cupola furnaces. M.V.C.

PATENTS

Coking retort oven heating wall of brickwork. JOSEPH DANIELS (Koppers Co.). U. S. 2,141,035, Dec. 20, 1938 (Jan. 23, 1936).

Foundation for checkerwork construction. G. L. DANFORTH, JR. (Open Hearth Combustion Co.). U. S. 2,139,729, Dec. 13, 1938 (March 2, 1936; July 24, 1937).

Furnace construction. L. H. HOSBEIN (M. H. Detrick Co.). U. S. 2,140,185, Dec. 13, 1938 (Oct. 8, 1934; renewed Oct. 26, 1937).

Furnace roofs, arches, etc. W. G. BOWER AND A. B. CLEWORTH & CO., LTD. Brit. 497,099, Dec. 30, 1938 (July 2, 1937).

Interlocking brick structure. L. H. MUELLER (Vitrefrax Corp.). U. S. 2,142,404, Jan. 3, 1939 (May 17, 1938).

Manufacture of mullitic cast refractories. R. HADDAN (Corning Glass Works). Brit. 497,253, Dec. 30, 1938 (Dec. 9, 1937).

Muffle flue. CHARLES W. SAXE (Norton Co.). Can. 377,963, Nov. 29, 1938 (March 5, 1937); see U. S. 2,087,215 (*Ceram. Abs.*, **16** [9] 285 (1937)). G.M.H.

Panel wall construction. J. E. BRINCKERHOFF AND A. M. KOHLER (Babcock & Wilcox Co.) AND C. S. REED AND V. W. SMITH (Lummus Co.). U. S. 2,144,598, Jan. 17, 1939 (May 14, 1935).

Process for the continuous extraction of aluminum oxide from bauxite. WILHELM FULDA AND RUDOLF WITTIG. U. S. 2,143,310, Jan. 10, 1939 (Feb. 3, 1936). A process for the continuous extraction of aluminum oxide from bauxite comprises contacting a continuous flow of heated caustic soda liquor under pressure with a stationary charge of coarse bauxite, effecting thereby a practically complete dissolution of the aluminum oxide contained in the bauxite, and treating the resulting sodium aluminate solution for the precipitation and recovery of the aluminum oxide.

Refractory for induction furnaces. H. C. FISHER (Norton Co.). U. S. 2,141,600, Dec. 27, 1938 (Oct. 10, 1935). The method of making a furnace lining for cuprous induction furnaces comprises mixing refractory oxide grain with a bond and a temporary binder, pressing the mixture into the shape desired, firing to vitrify the bond, placing the fired lining in a receptacle, filling the receptacle above the level of the lining with a liquid including a reducing agent which is such as to molten copper, placing the receptacle in a vacuum box, reducing the pressure, and removing the lining from the vacuum box thereafter.

Refractory linings for shaft furnaces. H. A. BRASSERT & CO., LTD., H. A. BRASSERT, AND J. S. FRASER. Brit. 496,289, Dec. 14, 1938 (April 23, 1937).

Setting of retorts for use in the distillation of solid carbonaceous substances. W. A. BRISTOW AND J. P. POSTLETHWAITE (Low Temperature Carbonisation, Ltd.). U. S. 2,143,972 and 2,143,973, Jan. 17, 1939 (July 26, 1935).

Suspended furnace wall. G. P. REINTJES. U. S. 2,143,280, Jan. 10, 1939 (Sept. 17, 1934).

Terra Cotta

Ceramic wall and floor tile. W. HENZE. *Baugilde*, **18** [27] 770–72; [28] 828–32 (1936); abstracted in *Referat. Silikatliteratur*, **4** [10] 4544 (1937).—H. reviews the use and manufacture of ceramic wall and floor tile in Germany. M.V.C.

Ceramics in architecture. GAETANO BALLARDINI. *Ceram. & Laterizi*, **1938**, Jan.–April, pp. 5–7.—Sculptured panels of large slabs of lithoceramics by Piccinelli exhibited at the International Exposition in Paris are illustrated. The technique of lithoceramics takes away from the brick the utilitarian function of a supporting element and transforms it into a substantial varicolored decorating material. M.V.C.

Defects in engobing. A. GALLASCH. *Ziegelwelt*, **68** [8] 85–87 (1937); abstracted in *Referat. Silikatliteratur*, **4** [8] 4332 (1937).—Tile produced from clay containing lime or salts which are affected by weather can not be made weather stable by means of engobes or glazes. The chief factor is to obtain an engobe which has a shrinkage similar to that of the tile. G. discusses the method of production, which is important for the adherence of the engobe. M.V.C.

Developments in the chemical industry in Canada. F. G. GREEN, W. H. DEBLOIS, AND G. S. WHITBY. *Trans. Amer. Inst. Chem. Engrs.*, **33**, 510–30 (1937). H.E.S.

Regeneration of *terra sigillata*. LUCIANO DÜRR. *Ceram. & Laterizi*, **1938**, Jan.–April, pp. 16–17.—*Terra sigillata* is the name applied to red pottery made by the Romans for domestic use from red clay covered by a hard and semilucid red glaze. According to Neumann (*Ceram. Abs.*, **11** [8] 461 (1932)) the shiny glaze was undoubtedly obtained by the use of boric acid probably brought from Tuscany. Schumann's method for making *terra sigillata* is given (see "Pottery—," *ibid.*, **15** [8] 249 (1936)). M.V.C.

ERRATUM

Vitreous tubing production. THEODORE PFAFF (Canadian General Electric Co., Ltd.). Can. 375,762, Aug. 16, 1938 (June 10, 1936). [This patent was erroneously published as No. 375,761 in *Ceram. Abs.*, **18** [1] 26 (1939)].

Whiteware

Cream-colored glaze for hard semiporcelain. ZENRO MIZUNO. *Jour. Japan. Ceram. Assn.*, **45** [540] 909–11 (1937).—The semiporcelain recently manufactured actively in Mino and Seto districts for export is a strong craze-proof china fired to Seger cone 8 and higher. M. deals with the best way of obtaining a cream-colored glaze for it. Uranium is the most satisfactory colorant. The U glaze must be fired in an oxidizing atmosphere, as it is discolored into green to black by a reducing flame. As an oxidizing atmosphere is obtained with difficulty at temperatures above 1100°C, the introduction of oxidizing auxiliary agents is advisable. Barium makes the glaze greenish. The best glazes consist of approximately 70 feldspar, 10 quartz, 15 limestone, and 5 parts zinc oxide. For the cream color, 1 to 5% of U compounds is added; 10 to 5% of pitcher (ground biscuit) may stabilize the glaze. Bodies colored slightly by iron are better than white bodies. Temperatures most liable to reduction are those from 1050° to 1150°C. M. recommends that slack coal be fed in small quantities at short intervals.
S.K.

Effect of slip densities on the shrinkage and vitrification of cast bodies. V. J. ROEHM. *Ceram. Forum*, **5** [7–9] 3 (1938).—Variations in slip densities affect the ultimate shrinkage and vitrification of the casting body used to make condiment sets, lamp shades, aerators, and clock faces for enameled stoves. H.E.S.

Errors in present methods of proportioning raw materials in potteries and a reliable method: II. JUNICHI ISOBE, TAKASHI FUKAGAWA, AND SEIJI KONDO. *Jour. Japan. Ceram. Assn.*, **44** [527] 785–88 (1936).—The significance of wet processes of proportioning ceramic raw materials is explained, and errors which may occur in the processes are discussed. The required weight of raw material (G) can be obtained by measuring the specific gravity of the slip (S) and its volume (V) according to the formula $G = (S-b)/(a-b)\cdot aV$, where a and b are the specific gravities of the raw material and water, respectively. The ratio of the maximum probable error in the required weight of raw material (dG) to the weight (G) can be expressed as follows:

$$\frac{dG}{G} = \frac{dV}{V} + \left[\frac{-bda}{(a-b)a}\right] + \left[\frac{-(a-S)\,db}{(a-b)\,(S-b)}\right] + \frac{dS}{S-b}$$

In the equation, errors in the measurement of V and b are almost negligible; the effect of error in the measurement of a may be large provided the value of a is comparatively small. The effect of error in the measurement of S is most unfavorable especially when its value is small. **III.** *Ibid.*, **45** [536] 543–49 (1937).—A process seeming most reliable for the wet proportioning of ceramic raw materials, experimental data on it, and a few simple but exact methods of measuring slip phase are given. The relation between the weight (X) of any slip, its volume (Y), dry weight (Z) of raw material contained in the slip, and specific gravities (a and b) of the material and water, respectively, can be expressed by the equation $(a-b)/b\cdot Z + bY = X$. If the weight of the raw material is fixed, $(a-b)/b\cdot Z$ is constant or K; therefore $X - bY - K = 0$. By using this "proportioning equation," the exact amount of any raw material can be taken, although the weight and volume of the slip must be measured at the same time. Trouble can be eliminated by the use of adequate machinery. Errors in the weight of the raw material do not exceed 0.5%. For Part **I** see *Ceram. Abs.*, **17** [2] 76 (1938).
S.K.

Nepheline-syenite in sanitary porcelain. C. J. KOENIG. *Jour. Amer. Ceram. Soc.*, **22** [2] 38–46 (1939).

Toughening ceramic coatings. J. H. BENRUBI. *Compt. Rend. 17me Congr. Chim. Ind.*, **1937**, pp. 178–81; *Brit. Chem. & Phys. Abs.–B*, **57** [7] 784 (1938).—Glazed surfaces may be toughened by chilling, as is done with glass, thus leading to an increase of thermal and mechanical resistance.

PATENTS

Artificial teeth. H. RAUTER AND H. S. RAUTER (trading as Vita Zahnfabrik H. Rauter). Brit. 497,021, Dec. 21, 1938 (June 12, 1936).

Automatic electric drip coffee maker. A. C. WILCOX. U. S. 2,143,046, Jan. 10, 1939 (July 28, 1936).

China and pottery-ware machines. G. W. LANE. Brit. 497,508, Jan. 4, 1939 (Nov. 16, 1937).

Expansion chamber for bushing insulators. T. F. BRANDT (Ohio Brass Co.). U. S. 2,142,233, Jan. 3, 1939 (Sept. 9, 1937).

Insulator construction. R. L. JENNER (Lapp Insulator Co., Inc.). U. S. 2,144,537, Jan. 17, 1939 (Oct. 7, 1937).

Insulator and method of manufacturing. J. J. TAYLOR (Ohio Brass Co.). U. S. 2,142,422, Jan. 3, 1939 (Nov. 10, 1936).

Making ceramic articles. R. E. GOULD. U. S. 2,143,003, Jan. 10, 1939 (Aug. 9, 1937). In a process of making a plurality of ceramic flatware articles which have substantially identical dimensions, the step comprises superposing for subsequent firing a plurality of ceramic elements comprising a plurality of leather-hard ceramic articles, preformed from plastic material, a leather-hard ceramic separating element, subjacent to each ceramic article, preformed from a plastic material which has the same physical properties as the plastic material from which the ceramic articles are formed and so shaped that a portion of the element is complementary to that portion of the reverse of a superposed article adjacent to its rim, that a portion of the element extends beyond the rim of the article, and that the thickness of that portion of the element extending beyond the rim of the article corresponds to the maximum thickness of the articles, a leather-hard setter, preformed from a plastic material which has the same physical properties as the plastic material from which the ceramic articles are formed, with at least a part of the obverse of the setter substantially identical to the obverse of the leather-hard ceramic articles, and a fired refractory setter, with the obverse of the fired setter complementary to the reverse of the leather-hard setter.

Manufacture of ceramic electrically insulating bodies. MARCONI'S WIRELESS TELEGRAPH CO., LTD. Brit. 496,762, Dec. 21, 1938 (June 10, 1936).

Spark plug. H. H. ARMSTRONG AND A. B. MENEFEE (Tungsten Electrodeposit Corp.). U. S. 2,143,853, Jan. 17, 1939 (Oct. 22, 1935). A. J. BELLEMORE. U. S. 2,143,048, Jan. 10, 1939 (Dec. 24, 1937). C. R. BENTON. U. S. 2,139,793, Dec. 13, 1938 (June 15, 1936). J. GABLER. Brit. 497,554, Jan. 4, 1939 (May 20, 1938). H. L. HALL. Brit. 496,271, Dec. 7, 1938 (May 25, 1937). B. HOPPS AND A. M. LODGE. Brit. 496,701, Dec. 14, 1938 (Aug. 21, 1937). CHARLES SMITH (Otis T. Hodge). U. S. 2,142,383, Jan. 3, 1939 (June 25, 1938).

Water closet. H. LEHMANN AND M. BOTTCHER. Brit. 496,157, Dec. 7, 1938 (Nov. 25, 1937).

Water-closet basins. AMERICAN RADIATOR CO. Brit. 496,895, Dec. 21, 1938 (Aug. 21, 1936).

Water closets with built-in evacuators. AMERICAN RADIATOR CO. Brit. 496,894, Dec. 21, 1938 (July 16, 1936).

Equipment and Apparatus

Allenite cemented tungsten carbide tipped cutting tools. ANON. *Edgar Allen News*, **17**, 266–69 (1938).—The properties of the sintered tungsten carbide material used for tools are described, and a comprehensive table is given for cutting velocities, shapes and angles of the cutting tips, and finishing velocities for steels, cast Fe, nonferrous metals, and several nonmetallic materials such as glass, porcelain, plastics, and marble. M.H.

Apparatus for measuring the total normal thermal emissivity of sheet materials in the temperature range

140° to 500°F. P. F. McDermott. *Rev. Sci. Instruments*, **8**, 185–92 (1937).—An apparatus for measuring the total normal thermal emissivity of sheet materials up to 3/8 in. in thickness at 140° to 500°F without contact or damage to the surfaces viewed is described. An analysis of possible errors shows the outer limits of absolute values to be within ±1% of black-body emission. A table of emissivities as measured is given with values from the literature included for comparison. By minimizing errors due to reflection, the values of the poor emitters are found to be somewhat lower than usually reported and are believed to be more accurate. H.E.S.

Deairing. Anon. *Brit. Clayworker*, **47** [560] 267–68 (1938).—A laminated structure in a column of clay may be caused by a badly designed set of blades or by the end of the shaft being too near the back of the mouthpiece. A backward movement of the clay into the vacuum chamber or into the inlet hopper of the machine is usually an indication that the blades are worn or that one or more unsuitable blades are being used. A wavy outline in the column of clay shows that the machine is being fed irregularly or that there is a serious irregularity in the drive. Another unusual defect is the shafts not being placed centrally in the barrels. Deairing may be incomplete because of too small a vacuum chamber. R.A.H.

Developments in bucket-excavator design. J. Schöbl. *Eng. Progress*, **19** [11] 209–11 (1938).—The development of German bucket excavators is traced. Illustrated. J.L.G.

Drying plant utilizing solar energy. E. Altenkirch. *Z. Ver. Deut. Ing.*, **82** [47] 1347–48 (1938).—A. describes a drying process in which circulating air is used which has been freed of its moisture by solar radiation; at the same time the flow of air is directed as desired. Good results have been obtained in this manner in drying lumber, coal dust, and granular material. In regions of plentiful sunshine this method is particularly simple and cheap. M.H.

Drying semidry-pressed brick. A. A. Shumilin. *Ogneupory*, **5** [8] 558–63 (1937).—Experiments showed that the drying of semidry-pressed brick must be performed at high temperatures for 8 to 16 hr. Tunnel kilns were found to be the most suitable. M.V.C.

Electric furnace for determination of pyrometric cone equivalents. W. L. Pendergast. *Bull. Amer. Ceram. Soc.*, **18** [1] 1–3 (1939).

Electric resistance furnaces. A. J. G. Smith. *Elec. Rev.*, **123** [3185] 824 (1938).—The design of a 4 x 14 ft. pit-type furnace is illustrated. For processes using temperatures of 650°C and lower, where forced circulation is needed to insure uniform temperature distribution, a heating shaft with a fan at the bottom is provided. For higher temperatures (up to 950°C) the side heating shaft is closed off from the furnace by heat-resisting steel dampers. The rating of the furnace is 320 kw. J.L.G.

Electron microscope. Anon. *Engineering*, **146** [3797] 474 (1938).—The construction of an electron microscope is described. A photomicrograph of clay at 18,700 diameters is shown. B.C.R.

Filtered ultra-violet rays in ceramics and glass manufacture. Anon. *Verre & Silicates Ind.*, **9** [28–29] 333 (1938).—Wood's light is a rapid means of controlling the efficacy of spectacles used as protection against ultra-violet rays. By placing a white paper in the observation field and holding the spectacles between the filter of the ultra-violet radiation lamp and this paper, a dark spot appears, the intensity of which indicates the efficacy of the spectacles against ultra-violet penetration. An obscurity scale for the quantitative analysis of ultra-violet rays through glass can thus be established. Certain pharmaceutical recipients showed luminescence after exposure to ultra-violet rays which permitted the differentiation between glasses colored with selenium and those colored with manganese and between copper and iron-cobalt glasses. Cerium gives a slight purple fluorescence. M.V.C.

Focusing method for X-ray powder spectroscopy. L. K. Frevel. *Rev. Sci. Instruments*, **8**, 475–77 (1937).—A convergent Soller-type slit, adaptable to a camera of arbitrary radius, selects those pencils of X-rays which emanate from a broad focal spot and impinge upon any selected point of the equator of the cylindrical camera. The diffracting powder is mounted on the camera wall in the form of a thin sheet which intercepts the wedge of X-radiation. In this manner all X-rays diffracted at the same Bragg angle are brought to a focus at the equator of the camera. H.E.S.

Fundamental problems in dry-pressing pulverized bodies. Shin-ichi Suzuki. *Jour. Japan. Ceram. Assn.*, **45** [538] 717–23 (1937).—Several difficulties in forming ceramic ware by dry-pressing powdered materials are pointed out, and a few of their causes are discussed with simple experiments and dynamical considerations. Diagrams show (1) curvatures of colored layers, (2) differences in the curvatures of a metal oxide, talc, and kaolin, (3) relation between time of pressing and compression, between pressure and compression, and between compressive strength and forming pressure, etc. S.K.

Immersion cell for polariscope use. E. E. Beeton. *Glass Ind.*, **19** [2] 51–53 (1938).—An immersion cell for determining stresses in glass-metal joints is described. Immersion media such as Russian mineral oil, C_6H_6, xylol, and $PhNO_2$ are recommended. Photographs show the difference in the strain picture seen in a polariscope with and without the use of such a cell. E.J.V.

Lag in indication and regulation of temperature in heating furnaces caused by the ceramic pyrometer protection sheath. K. Guthmann. *Stahl & Eisen*, **58**, 36 (1938).—A discussion based on the work of H. Euler and K. Guthmann ("Errors—," *Ceram. Abs.*, **15** [1] 32 (1936)) and E. Ernst ("Influence—," *ibid.*, [3] 102) is presented. L.R.B.

Lubrication of car-wheel bearings in ceramic operations. Anon. *Lubrication*, **23** [5] 56–60 (1937).—In average drier service, practice has indicated that a semisolid high-temperature grease is adaptable for the lubrication of bearings. Ordinarily, the lubricant should contain a mineral oil constituent of high viscosity, high flash point, and low carbon residue content. For kiln-car bearings, a light viscosity straight mineral oil is suitable with the addition of a small amount of graphite prior to usage. A heavier, more plastic type of lubricant is also suggested, such as a grease prepared from a low carbon-residue oil, a specially made soap, and perhaps a lubricant assistant such as graphite. The lubricant should be renewed when the wheel bearings are as cool as possible. H.E.S.

Particle sizer. Colloid Equipment Co. *Chem. Industries*, **43** [2] 164 (1938).—A sedimentation method of analyzing particle sizes below 44 μ provides accuracy of results, simplicity of design, speed and ease of manipulation, and low first cost. Accurate results are obtained in 2 hr. from samples of less than 5 g. The Palo-Travis particle sizer operates on the principle that dispersed particles of dimensions exceeding the colloidal in a confined fluid medium tend to settle under the force of gravity, and the rate of sedimentation is the means of measuring particle size. It is necessary then to measure accurately the rate of sedimentation. P.G.H.

Permanent ink for glass and porcelain. Stewart Research Laboratory. *Ind. Finishing*, **15** [1] 56 (1938).—This glass ink, brand LN, is available in black and white. It is noncorrosive in its action (can be kept in glass bottles) and is resistant to hot sulfuric, nitric, and hydrochloric acids and concentrated alkalis. It is insoluble in alcohol, acetone, turpentine, toluene, ethylene dichloride, and carbon tetrachloride. It can be applied with a steel pen or fine brush. Gentle warming increases its permanency. J.L.G.

Quartz-to-Pyrex joint. A. H. Weber and C. B. Bazzoni. *Rev. Sci. Instruments*, **8**, 170–71 (1937).—A method of sealing a quartz window 1 7/8 in. in diameter to a 1 3/8-in. bore Pyrex-brand tube is described. A method copied after Palmer (*Phys. Rev.*, **45**, 556 (1934)) is de-

scribed. Silver chloride is used to form a vacuum-tight joint. Illustrated. H.E.S.

Rate of sedimentation of flocculated particles. C. B. EGOLF AND W. L. MCCABE. *Trans. Amer. Inst. Chem. Engrs.*, **33**, 620–42 (1937).—The authors studied the sedimentation of flocculated particles, using (*a*) silica particles 16 μ in radius, (*b*) silica particles 5 μ in radius, (*c*) lead chromate, (*d*) zinc oxide, and (*e*) ferric oxide. The temperatures varied from 20° to 40°C, and the initial heights of the suspensions ranged from 12.5 to 61.7 cm. The concentrations varied from the point where the suspension no longer settled with a sharp line to the point where free settling was no longer exhibited. H.E.S.

Relative safe rates of drying of different clay sizes and shapes. H. H. MACEY. *Bull. Brit. Refrac. Research Assn.*, No. 38 (Sept., 1935); reprinted in *Brit. Clayworker*, **47** [560] 278–80 (1938).—M. gives the relative safe rates of drying of a number of different shapes and sizes of cubes and slabs of clay. The drying of flat slabs can be greatly expedited by air flow over them. The greatest safe drying rate of cubes can apparently be represented by the formula $1/R = A \cdot l^{1.6}$, where R is the safe rate of drying, l is the length of the side of the cube, and A is a constant. R.A.H.

Safe drying of large fireclay blocks. H. H. MACEY. *Bull. Brit. Refrac. Research Assn.*, No. 36 (March, 1935); reprinted in *Brit. Clayworker*, **47** [560] 280–82 (1938).—Maturing of clay in the molded piece is definitely beneficial in drying. The greatest safe rate of drying depends on the temperature at which it is performed, and there is an optimum temperature at which drying may proceed at the fastest rate. This temperature will naturally vary from clay to clay, but for the particular case given it lies between 45° and 50°C. The safe rate of drying increases with decrease of moisture content; thus, during maturing of a molded block, strict prevention of drying is unnecessary, and for the absolute minimum time schedule of drying the rate should be increased as the drying proceeds. R.A.H.

Small ball mill for laboratory work. BLOCH-ROSSETTI. *Eng. Progress*, **19** [11] 218 (1938).—A small porcelain ball mill is shaken in a horizontal position with an eccentric motion which causes two large porcelain balls to travel around the inside wall of the mill and do the grinding. High efficiency at low power is claimed on a large number of materials. [ABSTRACTER'S NOTE: The abstracter's experience with this type of mill was very disappointing. Excellent mixing was secured but no success was obtained in grinding materials much above talc in hardness.] Illustrated. See "Seventh—," *Ceram. Abs.*, **17** [3] 97 (1938). J.L.G.

Use of an alternating-current bridge in laboratory temperature control. M. BENEDICT. *Rev. Sci. Instruments*, **8**, 252–54 (1937).—An a.-c. bridge and amplifier for continuous temperature control of furnaces and thermostats is described. The circuit is simple and portable and can be made from standard electrical equipment. The power output of the control circuit is doubled for a change of 0.03% in the resistance of the regulating thermometer. Regulated power up to 500 w. may be obtained. The control circuit has been used to maintain the temperature of an oil bath and a furnace constant within 0.03°C per hr. H.E.S.

Value of hard-faced grinding rings. ANON. *Concrete, Cement Mill Ed.*, **46**, 254 (1938).—A comparison of the grinding efficiencies of (*a*) plain steel and (*b*) hard-faced steel grinding rings showed at 250 hr., (*a*) 75% and (*b*) 99.6%; at 450 hr., (*a*) 66% and scrapped and (*b*) 99.2%; at 3000 hr., (*b*) 95%. An alloy of cobalt, tungsten, and chromium was welded to the hard-faced ring, and after 3000 hr. it was refaced and returned to 100% efficiency. The hard-faced ring cost originally six times as much and refacing cost about the same as a plain steel ring. W.D.F.

BOOKS AND SEPARATE PUBLICATIONS

Measurement of the thickness of tin coatings on steel by a magnetic and an electromagnetic method. BRUCE CHALMERS, W. E. HOARE, AND W. H. TAIT. *Internat. Tin Research & Development Council Tech. Pub., Ser. A*, No. 66, 9 pp. (Nov., 1937).—Magnetic methods for estimating the thickness of coatings have found application for nonmagnetic coatings on magnetic bases or magnetic coatings on nonmagnetic bases. They show the advantages of rapidity, nondestruction of samples, and accuracy. This method consists in measuring the force necessary to pull a magnetized unit away from the surface of the specimen; the force depends on either the distance of the magnetic pole from the ferromagnetic surface or the thickness of the coating, if it is ferromagnetic. Instruments used and calibration are described. Nine references. C.B.J.

Optical Pyrometry. FRITZ HOFFMANN AND CARL TINGWALDT. F. Vieweg & Sohn, Brunswick, 1938. Reviewed in *Brit. Clayworker*, **47** [560] 285 (1938).—The importance of pyrometry in general and optical pyrometry in particular is increasing. The subject is treated in an up-to-date manner, and the book shows that this field is not complete but is in a most interesting stage of development. R.A.H.

PATENTS

Apparatus for pulverizing mineral aggregates. R. S. DEAN AND JOHN GROSS (Chicago Development Co.). U. S. 2,139,808, Dec. 13, 1938 (June 16, 1934). An apparatus for explosively disintegrating minerals comprises a supply chamber for receiving raw material, a preparation chamber adjacent to the supply chamber for treating the material, the supply and preparation chambers being in communication, an explosion chamber adjacent to the preparation chamber for receiving the treated material for explosively disintegrating it and for discharging the disintegrated material, the preparation and explosion chambers being in communication, an intake-control valve for sealing the supply chamber to the outside, a supply-control valve for sealing the supply chamber relative to the preparation chamber, a feed-control valve for sealing the preparation chamber relative to the explosion chamber, and a discharge-control valve for sealing the explosion chamber to the outside, whereby material charged into the supply chamber may be maintained above atmospheric pressure throughout its passage through the three chambers and whereby the preparation chamber may at all times be maintained at a pressure above atmospheric by closing the valves leading to the supply and explosion chambers, respectively, when these chambers are open to atmosphere.

Attrition apparatus. DANIEL DOYEN (Prest-O-Lite Storage Battery Corp.). Can. 378,567, Dec. 27, 1938 (Dec. 23, 1935). G.M.H.

Ball mill. RICHARD L. CAWOOD. Can. 378,471, Dec. 20, 1938 (March 7, 1936). FRANK E. MARCY. Can. 377,489, Nov. 1, 1938 (Aug. 1, 1936). G.M.H.

Combined flocculation and sedimentation apparatus. G. M. DARBY (Dorr Co., Inc.). U. S. 20,971, Jan. 10, 1939 (Jan. 29, 1938); reissue of original U. S. 2,095,923, Oct. 12, 1937.

Electrically heated furnace. HERMANN HENKE (G. Siebert Ges.). U. S. 2,140,228, Dec. 13, 1938 (March 27, 1936). A furnace for producing high temperatures comprises a heating chamber having walls and a plurality of electric heating resistance elements wholly within the chamber.

Extrusion process and apparatus. PAUL W. CRANE AND REUBEN T. FIELDS (E. I. du Pont de Nemours & Co.). Can. 378,251, Dec. 13, 1938 (Feb. 26, 1937). G.M.H.

Flocculation. G. M. DARBY, W. C. WEBER, AND A. J. FISCHER (Dorr Co., Inc.). U. S. 2,143,750, Jan. 10, 1939 (Oct. 21, 1938).

Method and apparatus for stenciling. T. H. SLOAN (Simplex Engineering Co.). U. S. 2,142,158, Jan. 3, 1939 (Jan. 7, 1937).

Pneumatic elevators for granular materials, etc. H. SIMON, LTD., AND H. WALDER. Brit. 496,843, Dec. 21, 1938 (Dec. 8, 1937).

Sandblast nozzle. EDWARD VAN DER PYL (Norton Co.). Can. 378,689, Jan. 3, 1939 (Sept. 28, 1936; in U. S., Oct. 1, 1935). G.M.H.

Spray gun. JOHN T. PETERSON. Can. 378,489, Dec. 20, 1938 (June 19, 1936; in U. S., June 21, 1935). G.M.H.

Temperature control device. WALLACE J. ETTINGER (Canadian General Electric Co., Ltd.). Can. 378,628, Jan. 3, 1939 (June 6, 1935). G.M.H.

Kilns, Furnaces, Fuels, and Combustion

Design and firing of kilns: X, Modern practice. ANON. *Brit. Clayworker*, **47** [559] 232–34 (1938).—Details of Hoffman kiln design are given including foundations, brickwork design, the center wall, and main arches. **XI.** *Ibid.*, [560] 262–64.—Kilns with segmental arches are described. For Parts **VI–IX** see *Ceram. Abs.*, **18** [1] 31 (1939). R.A.H.

Effect of firing time on crystallinity of floor tile. V. BODIN AND P. GAILLARD. *Arts du Feu*, **1** [2] 38–43 (1938).—An increase of firing time has no advantage. The substitution of new kilns for the usual intermittent type will shorten firing duration. F.E.V.

Effect of moisture of the ware on heat development in ceramic furnaces. B. HELAN. *Slavivo*, **16** [7] 115–16 (1935); abstracted in *Referat. Silikatliteratur*, **2**, 1616 (1935).—With increasing moisture of the ware, the heat developed by waste gases is insufficient; hence, the kiln works unsatisfactorily. A series of factors can not be taken into consideration, however, when using the simple equations developed. M.V.C.

Fuel must agree with kiln. JIROKICHI KUMAZAWA. *Jour. Japan. Ceram. Assn.*, **45** [535] 488–90 (1937).—Coal firing is apt to raise the kiln temperature too rapidly at first and to deposit carbon in the glaze and body because of an excessive production of volatile matter at the beginning which is not completely burned off before melting of the glaze is started. Pine wood is suitable for slow heating up; it generates less volatile matter which deposits more combustible carbon. Coal can be safely used (1) when ware, *e.g.*, earthenware, is fired at temperatures lower than Seger cone 8 with an oxidizing flame, (2) when ware, *e.g.*, hard porcelain, is fired at temperatures higher than cone 13, especially if a feldspathic glaze is applied, and (3) for ware which is not white. Coal firing rarely injures white porcelains, but it is very harmful to those decorated with underglaze colors. Coal firing is also injurious to ordinary oriental porcelains, which are usually fired at cones 9 to 12 in a reducing atmosphere, because the glaze begins to melt at temperatures between cone 1*a* and cone 4*a* before the carbon particles deposited in the glaze and body are completely burned off; a grayish white glaze results, therefore, which is due to residual carbon. The porcelains have been improved greatly by replacing a whole or a part of the limestone with magnesite or talc. K. recommends firing this ware with anthracite while it is being heated up slowly, firing with bituminous coal after it is hot enough, and leading hot air into an opening at the base of the stack when smoky gases are produced. S.K.

Gas-fired tunnel kilns. A. J. G. SMITH. *Gas Age*, **83** [1] 30 (1939).—S. gives data on gas consumption using a 470-B.t.u. gas for firing various ceramic materials. B.C.R.

Gasification. M. SIRON. *Jour. Usines Gaz*, **62** [10] 224–28; [12] 284–88 (1938).—S. gives general considerations on physicochemical equilibria governing the reactions of dissociation of water vapor, carbon dioxide, and carbon monoxide. R.W.D.

Ignition of coal on a grate. P. O. ROSIN AND H. R. FEHLING. *Jour. Inst. Fuel*, **11**, 102–17 (1937).—Experiments were conducted to show the practical significance of the time factor in the ignition of coal. H.E.S.

Ignition of fuel beds. A. C. DUNNINGHAM AND E. S. GRUMELL. *Jour. Inst. Fuel*, **11**, 117–22, 129–33 (1937).—The problem of ignition on a large scale somewhat similar to that obtained on a chain grate stoker is described. H.E.S.

Kilns for firing refractory brick. TAIZO KURODA. *Jour. Japan. Ceram. Assn.*, **45** [540] 871–72 (1937).—K. deals with the features of kilns used for refractory brick in Japan. (1) Rectangular kilns are widely used but are weak in structure and require frequent repair. (2) The *Nobori gama* (ascending kiln) is peculiar to Japan. It is a semicontinuous kiln built on a slope and fired with coal or wood. It is simple and inexpensive. It is not suitable for high temperatures and is used only for low-grade ware. (3) The *Teppo gama* (gun kiln) of the Mitsuishi district is a horizontal semicontinuous kiln and consists of up to 20 chambers, each holding up to 3500 brick. The maximum temperature is about Seger cone 8 like that of the *Nobori gama*. Products are apt to be overfired or soiled. (4) Chamber kilns are uneconomical if each chamber is small. High temperatures are not easily produced in them. (5) Round kilns are universal in America. In 1915, eight 12-m. American kilns, holding 450 tons of silica brick, were built in Yawata. An inside wall of 3.5 m. may be too high. More uniform products are obtained and repair costs are less, compared with those of rectangular kilns. (6) Tunnel kilns produce uniform brick, consume less fuel, and require little labor. At the Yawata Steel Works, blast-furnace gas and coke-oven gas are used. Oils may cost too much in the future. Producer gas from coal contains tar; that from coke is unfit for high temperatures. S.K.

Pottery firing by gas. A. MACKAY. *Pottery & Glass Record*, **20** [11] 301 (1938).—M. discusses the use of town gas for firing pottery. Fuel cost alone is not a sufficient basis of comparison; the total cost of producing the finished article is the only true basis. In the pottery area around Stoke-on-Trent there are 56 continuous tunnel kilns and six intermittent kilns fired by town gas, replacing 65,000 tons of coal by gas and eliminating a blanket of smoke 6 in. thick over an area of 12 sq. miles. Town gas has been adapted to almost every heat requirement in pottery production. See "Gas—," *Ceram. Abs.*, **16** [5] 158 (1937). A.B.S.

Regenerative heating in tunnel kilns. E. SCHIRM. *Keram. Rundschau*, **46** [13] 142–45; [16] 179–81; [17] 193–95 (1938).—S. describes the Stein tunnel kiln with regenerative heated firing zone and the development of the Koppers' kilns. Koppers separated the three zones completely; later he built the double tunnel kiln with lateral regenerators and the double tunnel with transport of ware in opposite directions. The tendency of hot gases to ascend is counteracted by intermediate doors. Koppers' next step was the multiplication of burners. The use of these kilns is limited to the firing of high refractory brick. 14 illustrations. F.E.V.

Tunnel kiln firing: IV. M. MARCEL CHAIN. *Trans. Ceram. Soc.*, **37** [11] 517–32 (1938).—C. describes the Sofim (French) kiln which permits of open firing of ware, *e.g.*, without the use of either muffles or saggers. For Parts **II–III** see *Ceram. Abs.*, **18** [1] 32 (1939). R.A.H.

Tunnel kilns in the heavy clay industry. G. C. MATTHEWS. *Trans. Ceram. Soc.*, **37** [11] 506–16 (1938); see *Ceram. Abs.*, **17** [10] 337 (1938). R.A.H.

SEPARATE PUBLICATIONS

Insulating effect of some materials in doors of circular kilns. A. P. HAGENDOORN. *Mededeel. Labor. N. V. Vlamovenstraatklinker*, 9 pp. (Nov., 1935); abstracted in *Referat. Silikatliteratur*, **3** [5] 2859 (1936).—H. studied the insulating effect of door-filling materials in a chamber circular kiln with overhead flame. Porous materials such as pumice sand, ground slag, etc., are suitable. M.V.C.

Mechanism of combustion of coal. MARTIN A. MAYERS. *Amer. Inst. Mining & Met. Engrs. Tech. Pub.*, No. 575, 17 pp. (1934).—Radiated heat makes a particle of powdered coal first lose its volatile matter, usually without either being ignited. Further heating ignites it, and it becomes hotter rapidly, the temperature rising about 1000°C in 0.1 sec. Exhaustion of the oxygen in contact stops this rise. The rate of combustion of a particle varies approximately with its radius and as the 0.4 power of the relative velocity in its atmosphere; the effect of temperature has not been determined. In grate-fired furnaces the analysis is complicated by the interference of the particles in the bed, and the properties of the coal become important; the same stages, however, may be found. The ultimate limit of the rating with both pulverized and grate-fired coal depends on the reactivity of the coke. The limit is not reached with pulverized coal, as the rate is dependent on the speed of burning. With grate fuel, attainment of high rating requires high reactivity, high thermal diffusivity, and a strong and dense fuel. Ash will not affect the rate unless clinkers form. High rating with pulverized coal requires a reactive coal containing some easily ignitable volatile matter. W.D.F.

PATENTS

Gas-generating apparatus. ALFRED ZEUCH (Azett-Gas-Apparate-Bau G.m.b.H.). Can. 378,211, Dec. 13, 1938 (Aug. 19, 1936). G.M.H.

Tunnel kiln. JAMES T. ROBSON AND GEORGE R. SYLVESTER (Ferro Enamel Corp.). Can. 377,296, Oct. 25, 1938 (Jan. 30, 1937); see U. S. 2,088,554 (*Ceram. Abs.*, **16** [10] 309 (1937)). G.M.H.

Geology

Application of spectroscopic methods to problems of petroleum geology and engineering. ELDON A. MEANS. *Petroleum Engr.*, **9** [13] 37–40 (1938).—M. describes the use of the optical spectrograph and the X-ray diffraction technique for determining elements and minerals in various geological strata and ground waters. P.G.H.

Bauxite deposits at Gánt, Hungary. QUENTIN D. SINGEWALD. *Econ. Geol.*, **33** [7] 730–36 (1938).—One of the world's largest reserves of readily accessible bauxite is located near Gánt. The deposits, discovered in 1915, have only recently been exploited. Present workings consist of two open pits, each containing a continuous layer of bauxite from 15 to 30 m. thick. The origin and geology of the deposits are considered. The ore analyzes 50 to 63 Al_2O_3, 15 to 30 Fe_2O_3, and 2 to 4% SiO_2. Total reserves are estimated at 120 million tons. J.L.G.

Bentonite. ANON. *Verre & Silicates Ind.*, **9** [32] 370–72 (1938).—The properties and uses of bentonite are given. M.V.C.

Ceramic uses of volcanic ash. NORMAN PLUMMER. *Bull. Amer. Ceram. Soc.*, **18** [1] 8–11 (1939).

Chromite. ANON. *Mineral Ind.*, **46**, 91 (1937).—Brazilian chrome deposits in Santa Luzia and Campo Formoso (Bahia) consist of 280,000 metric tons in sight and a total reserve of 4,000,000 metric tons. This ore assays 34 to 51% Cr_2O_3. The low-grade ore can be concentrated to produce a product of 51 to 52% Cr_2O_3. B.C.R.

Classification of magnesium nickel silicates containing water. G. S. GRIZAZHENKO. *Mineral. Syr'e*, **11** [3] 5–11 (1936); abstracted in *Referat. Silikatliteratur*, **4** [9] 4405 (1937).—G. classifies magnesium-nickel silicates containing water and reviews their crystallographic and physical properties. M.V.C.

Diatoms. B. V. SKVORTSOV. *Philippine Jour. Sci.*, **65** [4] 399 (1938).—S. describes in detail the diatoms found in Kenon Lake, Siberia. B.C.R.

Diatoms from Argum River, Hsing-An-Pei Province, Manchukuo. B. V. SKVORTSOV. *Philippine Jour. Sci.*, **66** [1] 43 (1938). B.C.R.

Diatoms from a peaty bog in Lianchiho River valley, eastern Siberia. B. V. SKVORTSOV. *Philippine Jour. Sci.*, **66** [2] 85 (1938). B.C.R.

Flotation of California magnesite. ERIC SINKINSON AND S. D. MICHAELSON. *Trans. Amer. Inst. Mining & Met. Engrs.*, **129**, 235–40 (1938). W.D.F.

Formation of hydrated calcium silicates at elevated temperatures and pressures. EINAR P. FLINT, HOWARD F. MCMURDIE, AND LANSING S. WELLS. *Jour Research Nat. Bur. Standards*, **21** [5] 617–38 (1938); R.P. 1147. Price 10¢.—An X-ray investigation of the crystalline hydrated calcium silicates which occur naturally as minerals indicated that the following are distinct compounds: okenite, $CaO \cdot 2SiO_2 \cdot 2H_2O$; gyrolite, $2CaO \cdot 3SiO_2 \cdot 2H_2O$; crestmoreite, $2CaO \cdot 2SiO_2 \cdot 3H_2O$; xonotlite, $5CaO \cdot 5SiO_2 \cdot H_2O$; afwillite, $3CaO \cdot 2SiO_2 \cdot 3H_2O$; foshagite, $5CaO \cdot 3SiO_2 \cdot 3H_2O$; and hillebrandite, $2CaO \cdot SiO_2 \cdot H_2O$. Riversideite is apparently not a distinct mineral and is probably the same compound as crestmoreite. Crystalline preparations having X-ray patterns identical with those of gyrolite, xonotlite, and foshagite were synthesized by hydrothermal treatment of calcium silicate in the form of the anhydrous crystalline compounds, glass and amorphous hydrate. Other compounds formed were cristobalite, wollastonite, and pseudowollastonite. A low-temperature modification of anhydrous tricalcium disilicate, which inverts to the usual form at 1024° ±5°C, resulted from the action of water vapor on tricalcium disilicate at 500°C, 380 atm. Gyrolite was obtained at temperatures between 150° and 400°C, wollastonite at 400°C and higher, and foshagite at 300° to 350°C. Attempts to prepare okenite, crestmoreite, afwillite, and hillebrandite were unsuccessful. Treatment of tricalcium and dicalcium silicates with water at room temperature for several years gave crystalline alteration products different from other known hydrated calcium silicates. Attempts to isolate and identify the hydrated calcium silicate binding material in commercial sand-lime brick and in laboratory-prepared brick were unsuccessful. Applications of the results to the autoclave testing of cements are discussed. R.A.H.

French fluorspar and Belgian market. V. CHARRIN. *Verre & Silicates Ind.*, **9** [33] 381–83 (1938).—Fluorspar, CaF_2(48.90% fluorine), is used in enameling and crystal-glass manufacture. In large amounts fluorspar makes glass opalescent, and it is used in art ceramics to render glass opaque like porcelain. C. describes the fluorspar lodes in France and recommends that of Esterel to supply the Belgian market because of the enormous deposits which are of good quality and are easily exploited. It is located near the port of St.-Raphaël where export is facilitated. Belgium imports fluorspar because its own deposits contain calcite and barite impurities. M.V.C.

Froth flotation of fluorspar. DAVID R. MITCHELL, H. E. GROSS, AND H. E. OEHLER. *Amer. Inst. Mining & Met. Engrs. Tech. Pub.*, No. 999; *Mining Tech.*, **2** [6] 13 pp. (1938).—The whole sample had 10% passing 200-mesh and a composition of 47 CaF_2, 31 $CaCO_3$, and 22% SiO_2. The CaF_2 was more concentrated in the coarse and fine fractions with more of the $CaCO_3$ in the intermediate fractions. Best results were obtained by using a cell temperature of from 60° to 90°C; sodium carbonate, 1 lb./ton; p_H, 8.5; water glass (density 1.40), 0.12 lb./ton; and oleic (or stearic) acid, variable, about 0.095 lb./ton. Tap water is satisfactory. Fluorite coarser than 65-mesh was hard to float. W.D.F.

Froth flotation of southern barite ores. R. G. O'MEARA AND G. D. COE. *Trans. Amer. Inst. Mining & Met. Engrs.*, **129**, 241–45 (1938). W.D.F.

Fundamental properties of nepheline-syenite. C. J. KOENIG. *Jour. Amer. Ceram. Soc.*, 22 [2] 35–38 (1939).

Hydrothermal reaction between alkali solutions and kaolin: II. SHOICHIRO NAGAI. *Jour. Japan. Ceram. Assn.*, **45** [537] 605–14 (1937).—Alkali kaolin or artificial nepheline hydrate, $R_2O \cdot Al_2O_3 \cdot 2SiO_2 \cdot nH_2O$, is pro-

duced by the hydrothermal reaction under pressure between NaOH or KOH and kaolin. The Na product, $Na_2O \cdot Al_2O_3 \cdot 2SiO_2 \cdot H_2O$, can be obtained even under atmospheric pressure, while the K product, $K_2O \cdot Al_2O_3 \cdot 2SiO_2 \cdot {}^1/_4H_2O$, is produced only under high pressures. On treating the alkali kaolin with a 5 to 10% solution of $CaCl_2$ or $MgCl_2$ under a steam pressure of 30 to 50 atm., $0.5(Na,K)_2O \cdot 0.5(Ca, Mg)O \cdot Al_2O_3 \cdot 2SiO_2 \cdot nH_2O$ was obtained. Pyrophyllite, $Al_2O_3 \cdot 4SiO_2 \cdot H_2O$, reacts with NaOH solution under pressure, producing $Na_2O \cdot Al_2O_3 \cdot 2SiO_2 \cdot nH_2O$ and Na silicate. Similar K compounds are obtained at a higher temperature. Pyrophyllite was separated from kaolinite by heating the mixture with a boiling 15% solution of NaOH under atmospheric pressure for 3 hr.; by this treatment, a residue consisting of pyrophyllite and an alkali kaolin, $Na_2O \cdot Al_2O_3 \cdot 2SiO_2 \cdot H_2O$, was produced. It was dissolved away by treating the residue with 10% HCl and then with 5% NaOH solution. According to N., Roseki or agalmatolite of Shokozan in Hiroshima Prefecture alone is almost pure pyrophyllite, while that of Zenranando in Korea and Hakusan in Santosho consists of kaolinite and a small amount of diaspore; that of Mitsuishi in Okayama Prefecture is a mixture of pyrophyllite and kaolinite although it may be composed chiefly of beidellite, $Al_2O_3 \cdot 3SiO_2 \cdot xH_2O$. For Part I see *Ceram. Abs.*, **16** [11] 354 (1937). S.K.

Kaolin in France. V. CHARRIN. *Céram., Verrerie, Email.*, **6** [9] 257–59 (1938).—The following less well-known kaolin deposits of France are described: (1) Brittany, (2) Drome and Isère, and (3) Chasteaux (Corrèze). M.V.C.

Kaolin of Furbara, Italy. RENATO MORETTI AND LUIGI PERETTI. *Ceram. & Laterizi* [Supp.], **1938**, May–Aug.—The exploitation of kaolin has made great progress in Italy. The deposits of Furbara were studied, and the composition and properties of the kaolin were determined. The purified mineral is a true kaolin with physicomechanical properties similar to those of foreign kaolins used in ceramics and is of a quality adequate to justify the expense of establishing a purification plant. Data on the properties are given. M.V.C.

Kaolin and its matrix rock. V. CHARRIN. *Céram., Verrerie, Email.*, **6** [10] 293–94 (1938).—Kaolin, $Al_2O_3 \cdot 2SiO_2 \cdot H_2O$, is derived from the decomposition of feldspar according to the formula $K_2O \cdot Al_2O_3 \cdot 6SiO_2 + 6H_2O = K_2O \cdot SiO_2 \cdot H_2O + Al_2O_3 \cdot 2SiO_2 \cdot H_2O + 3SiO_2 \cdot H_2O$. The alkaline silicate and the hydrated silicate are soluble in water, leaving the white hydrated aluminum silicate (kaolin). As the dissolution of the hydrated silicate is much slower than that of the alkaline silicate (either sodium or potassium), this substance is usually imperfectly eliminated. Magnesia and lime are other impurities. The best kaolins of Saint-Yrieix, China, or Saxony rarely contain less than 52% silica or more than 41% alumina with 1 to 2.5% alkalis or alkaline earths. The essential differences between two principal French kaolinic regions, Limousin (kaolin derived from pegmatites) and Brittany (kaolin derived from granulite matrix rock), are discussed. The enormous resources of kaolinic clay found in Brittany, if judiciously exploited, would be sufficient to supply the French market. M.V.C.

Large-diameter core drill for geologic exploration. BERLEN C. MONEYMAKER AND PORTLAND P. FOX. *Amer. Inst. Mining & Met. Engrs. Tech. Pub.*, No. 1000; *Mining Tech.*, **2** [6] 12 pp. (1938).—A detailed description of the method of drilling to determine the geology of the dam sites of the Tennessee Valley Authority is given. It should be valuable in exploring certain mineral deposits. Minerals such as talc, steatite, pyrophyllite, vermiculite, bentonite, gypsum, sulfur, and salt are too soft or too soluble to be recovered successfully in small cores. Other materials, *e.g.*, marble, limestone, and serpentine, may contain defects which can not be properly evaluated from small cores. Cores up to 72 in. in diameter may be drilled. W.D.F.

Mineralogy. J. ORCEL. *Rev. Gén. Sci.*, **48** [16] 423–32 (1937).—Modern improved methods of investigation have greatly advanced the knowledge of mineral species. O. summarizes the research work of W. L. Bragg on silicates and comments on synthetic minerals, geochemistry, and processes involving the separation of natural minerals. R.W.D.

Mining and beneficiation of barite at Cartersville, Georgia. DAVID P. HALE, JR. *Amer. Inst. Mining & Met. Engrs. Tech. Pub.*, No. 973; *Mining Tech.*, **2** [5] 13 pp. (1938).—In 1937, 68% of the barite shipped was used for lithopone, 15% for barium chemicals, 13% for ground barite, and 4% for glassmaking. The market for lithopone is decreasing, but the glass market is increasing, as is that for ground barite, which is used to weight the muds when drilling oil wells. W.D.F.

Physicotechnical properties of cast rock. A. S. GINSBERG AND F. G. SEMENOV. *Mineral. Syr'e*, **11** [3] 19–29 (1936); abstracted in *Referat. Silikatliteratur*, **4** [10] 4558 (1937).—Data on the heat capacity, coefficient of linear expansion, cooling curves, electrical conductivity, and viscosity of cast diabase and other rocks are given in tables. M.V.C.

Quartzites of the Bobrov deposits (south Urals). V. F. SAMOĬLOV AND V. D. PETROVA. *Ogneupory*, **5** [10] 725–31 (1937).—Characteristics of the large deposits of crystalline quartzites are dealt with. M.V.C.

Thermal capacity and thermal reactions of mineral raw materials. A. S. BAZILEVICH. *Mineral. Syr'e*, **10** [4] 55–63 (1935); abstracted in *Referat. Silikatliteratur*, **4** [6] 4118 (1937).—The average specific heat of 18 natural raw materials used in the Russian ceramic industry is given in a table. The specific heat was measured at temperatures from 300° to 1200°C. The materials tested were kaolins and clays, zircon, talc, chromite, calcite, magnesite, andalusite, kyanite, bauxite, and beryl. See "Heat—," *Ceram. Abs.*, **14** [3] 82 (1935). M.V.C.

Thermal dehydration of bentonites. MUNE UTIDA. *Jour. Japan. Ceram. Assn.*, **45** [540] 873–80 (1937).—U. studied the thermal dehydration of a typical yellow and two white purified bentonites produced in Japan. Empirical formulas of the yellow bentonite and a white bentonite were approximately $Al_2O_3 \cdot 5SiO_2 \cdot H_2O$ and $Al_2O_3 \cdot 6SiO_2 \cdot 2H_2O$, respectively. Dehydration curves of these three samples are of the same type. They are S-shaped between 50° and 130°, straight between 100° and 600°, and hooklike between 600° and 1100°C. Air-dry samples lose about 60% of the total water at 50° to 130°, forming S-shaped curves like those of acid clays and colloidal silica or alumina. The imbibing property is reduced abruptly at about 600°. The curves between 100° and 1100° are characteristic for bentonites. The S-shaped section corresponds to gel water, the straight part to the dehydration of the loosely fixed water of colloidal silicic acid, and the hooklike part to the constitutional water of crystalline Al silicate. Empirical formulas of pure bentonites are $2Al_2O_3 \cdot (10-x)SiO_2 \cdot H_2O \cdot xSiO_2 \cdot aq$. Micelles in water may have such a construction that very thin crystalline layers of the molecular order of Al-silicate plate hold colloidal silica between them with ample water in common. The high water-imbibing property can be attributed to the hydration and diffusion powers of swarmed ions which are distributed between the plates. S.K.

Thermal resistance of natural acid-stable minerals. G. P. EFIMOV AND V. N. GRIGOROVICH. *Mineral. Syr'e*, **11** [8–9] 21–28 (1936); abstracted in *Referat. Silikatliteratur*, **4** [10] 4510 (1937).—The thermal resistance of andesite, beshtannite, and granite was tested. These minerals are used as linings for absorption towers in which temperatures up to 900° are reached. Tables show the comparative properties of these materials and of glass, porcelain, and quartz glass. M.V.C.

Tripoli deposits of the western Tennessee Valley. E. L. SPAIN, JR. *Trans. Amer. Inst. Mining & Met. Engrs.*, **129**, 501–15 (1938). W.D.F.

X-ray evidence of montmorillonite in kaolin clay. GUSTAV KEPPELER AND GERHARD AURICH. *Sprechsaal*, **71** [25] 307–308 (1938).—X-ray pictures show the presence of montmorillonite in Zettlitz kaolin and in Kärlich blue clay and bentonite after heating to 350°. M.V.C.

X-ray study and valuation of the technological properties of quartzites. B. Ya. Pines and K. I. Dorogoi. *Ogneupory*, **5** [9] 603–13 (1937).—The basic technological properties of quartzites are qualitatively characterized by their structure (dimensions of the elementary cell) and their texture. M.V.C.

Yamagata bentonite: IV. Mune Utida. *Jour. Japan. Ceram. Assn.*, **45** [539] 800–807 (1937).—Yamagata bentonite is the only yellow type found in Japan. Bentonite number, $h_0(h_m - 1)/W_0$, of the yellow bentonite is generally larger than that of any white one. Fineness of the washed yellow bentonite has no effect on the result of the method. Most natural bentonites swell normally, *i.e.*, the tablet produces a single swelled cone. Abnormal forms, however, result in solutions of electrolytes. Errors with the method are mostly within 5%. For Part III see *Ceram. Abs.*, **17** [4] 158 (1938). S.K.

BOOKS AND SEPARATE PUBLICATIONS

Introductory Economic Geology. W. A. Tarr. McGraw-Hill Book Co., New York, 1938. 2d ed. 645 pp., 257 figs. Price $5.00. Reviewed in *Econ. Geol.*, **33** [7] 778–79 (1938).—This text is designed for students who possess a rudimentary knowledge of geology. J.L.G.

Investigation of Some Virginia Feldspars. Paul S. Dear, A. A. L. Mathews, and John W. Whittemore. *Virginia Polytech. Inst. Eng. Expt. Sta. Bull.*, No. 35, 48 pp. (Dec., 1938).—A field survey of eight Va. counties, covering an area of more than 3500 sq. mi., was made. A sketch map of the surveyed area, showing the location of samples and deposits, and a diagrammatic geologic cross section are included. The field samples were processed in the laboratory to approach commercial fineness specifications for ceramic body materials. The processed samples were subjected to the following laboratory tests: (1) mechanical analysis, (2) chemical analysis, (3) petrographic examination, (4) softening-point determination, (5) fusion behavior over a range of temperature, and (6) fired color and appearance. The feldspar deposits of Va. are discussed in relation to the geology of the investigated area. The results of the laboratory tests are discussed with reference to the use and possibilities of Va. feldspars as raw material components of (1) whiteware bodies and glazes, (2) vitreous enamels, and (3) glasses. The excellent quality of the feldspars and the concentration of workable deposits in relatively narrow belts in proximity to the three major railroads serving the investigated area make more intensive commercial recovery feasible and promising. Illustrated. P.S.D.

Lexicon of Geologic Names of the United States (Including Alaska). M. Grace Wilmarth. *U. S. Geol. Survey Bull.*, No. 896, Part 1, pp. 1–1244; Part 2, pp. 1245–2396 (1938). Supt. of Documents, Govt. Printing Office, Washington, D. C. Price $2.50. The compilation of this dictionary of geologic names, a by-product of the work of the Committee on Geologic Names of the U. S. Geological Survey, was begun more than 25 years ago. The number of names applied to geologic formations has grown until the lexicon now probably includes three times as many names as were in the literature when the work was started. The formal definitions of the formations state briefly the lithologic character, thickness, geologic age, stratigraphic relations to underlying and overlying formations, and type locality. Definitions and redefinitions are given only to the units found in the U. S. and Alaska, but the names and current age designations of the geologic units of Canada, Mexico, Hawaii, the West Indies, and Central America are also listed, together with citations to the publications in which they were defined. R.A.Heindl

Manganese Compounds in Industry. A. W. Groves, Imperial Inst., Mineral Resources Dept. 2d ed. 164 pp. Price 3s 6d. Reviewed in *Chem. Trade Jour.*, **103**, 389, 396 (1938). L.R.B.

Prospecting and sampling of undeveloped fireclay deposits. C. R. Fettke. *Amer. Refrac. Inst. Tech. Bull.*, No. 73, 10 pp. (Dec., 1938).—The prospecting of an undeveloped fireclay deposit can be divided into three stages: (1) locating undeveloped deposits, which consists in studying geologic surveys, studying outcrops of the deposit, taking preliminary samples, and following the continuity of the deposit; (2) preliminary exploration to determine whether the thickness and possible extent of the deposit and the character of the clay warrant more thorough prospecting; and (3) systematic prospecting and sampling to determine whether actual development of the property is feasible. The type of sampling, drilling, crushing, and sample reduction are discussed. The thoroughness with which an undeveloped deposit should be prospected and sampled depends on the amount of money required to develop it, the degree of regularity of the deposit, its location with respect to transportation facilities, and whether the raw material is to be sold or used directly in a plant. H.E.S.

Refractory Clays of Western Oregon. Preliminary Report. Hewitt Wilson and Ray C. Treasher. *Oregon Dept. Geol. & Mineral Ind. Bull.*, No. 6, 93 pp. (1938).—The work was undertaken in anticipation of the refractory clay requirements of metallurgical industries that should be attracted to the lower Columbia area by the availability of electrical power at favorable rates from Bonneville Dam. The economic aspects are stressed. The quality of clays fusing at cone 30 or more is considered by means of physical and chemical tests of the clay; the estimated quantity and mining and transportation conditions are discussed, and recommendations are made for continued work. Geologic data were secured incidental to the main project, but conclusions based on these data must be considered tentative. Such conclusions are submitted as contributions to a complex subject on which little work has been done. P.G.Herold

Statistical Year Book for 1938 of the International Tin Research and Development Council. 206 pp. Typical tin analyses from all producing sources are given in a table. Export tonnages as compared to quotas are given. The International Tin Control Scheme is briefly summarized. World tin production is given in tables and shown by bar graph. Tin production and imports and exports of tin ore are statistically presented for the countries of Europe, Africa, America, Asia, and Oceania. The production of secondary tin; tin stocks, annual and monthly averages; stocks in percentages of consumption; prices at leading centers; prices of tin cans, solder and babbitt metal, and tin compounds; prices of scrap; and indices of commodity prices are presented. Applications of tin and its alloys are summarized and shown in a flow sheet, statistically and by graph. Tin used in manufacturing in all countries is shown statistically and by graphs. World tinplate production, consumption, imports, and exports are given for the various countries. Similar information is presented for canned food, solder, white-base bearing alloys, bronze, collapsible tubes, tin foil, pewter, tin compounds, and type metal. Data are given on automobile registration, production of automobiles, tin used in automobile manufacture, tin used in railways, and railroad rolling stock. C.B.J.

PATENTS

Treatment of natural silicates. G. A. Blanc and F. Jourdan. Fr. 833, 877, July 1, 1937; *Chem.-Ztg.*, **62** [91] 827 (1938). D.A.B.

Well-drilling mud. Charles F. Teichmann (Texaco Development Corp.). Can. 377,312, Oct. 25, 1938 (Feb. 7, 1938; in U. S., Feb. 24, 1937). William V. Vietti and Allen D. Garrison (Texaco Development Corp.). Can. 377,310, Oct. 25, 1938 (Oct. 15, 1936; in U. S., Oct. 26, 1935 and July 21, 1936). Can. 377,311, Oct. 25, 1938 (Nov. 29, 1937; in U. S., Dec. 8, 1936). G.M.H.

Chemistry and Physics

Accomplishments and future of chemical physics. H. C. UREY. *Rev. Sci. Instruments*, **8**, 223–27 (1937).—Some of the more important technical processes developed in the closing years of the 19th and the beginning of the 20th Century are (1) utilization of coal tar, (2) development of the petroleum industry, (3) fixation of atmospheric nitrogen, (4) development of plastics and rubber, (5) manufacture of artificial textiles and fabrics, (6) improvements in ceramics and glass, (7) hydrogenation of coal, (8) manufacture of synthetic or derived foods, and (9) application of protective coatings. Since the source of energy from the sun is not disappearing as rapidly as petroleum, coal, and other natural resources, the man of the future may have to live on the energy derived from the sun. The fuel supply will probably be derived from plants developed for the purpose. The real objective of scientific men, however, is to abolish drudgery, discomfort, and want from the lives of men and bring pleasure, comfort, leisure, and beauty. H.E.S.

Chemistry and X-ray analysis. R. VIALLARD. *Nature* [Paris], No. 3028, pp. 4–8; No. 3029, pp. 37–43 (1938).—After reviewing the principle of X-ray analysis and its application to the study of chemical compounds, V. summarizes roentgenographic investigations carried out on silicates which neither the chemist nor the mineralogist has been able to classify in a satisfactory manner. X-ray diagrams have indicated that the lattice of the molecular edifice of silicates and of aluminosilicates is made of tetrahedral groupings of atoms of oxygen, the center of the groupings being occupied by an atom of silicon or aluminum. According to their particular texture, silicates are divided into four classes where the molecular structure is formed by (*a*) isolated groups of the $SiO_4^{::}$ type (topaz, zircon), (*b*) netlike groupings (hornblende), (*c*) associated groupings in layers (shale, mica, kaolin, talc), and (*d*) three-dimensional groupings (quartz, zeolites, ultramarine). R.W.D.

Dielectric properties of insulating materials. E. J. MURPHY AND S. O. MORGAN. *Bell System Tech. Jour.*, **16** [4] 493–512 (1937).—A qualitative account of the way in which dielectric constant and absorption data have been interpreted in terms of the physical and chemical structure of materials is given. The dielectric behavior of materials is determined by the nature of the polarizations which an impressed field induces in them. The various types of polarization which have been demonstrated to exist are listed with an outline of their characteristics. H.E.S.

Equilibria in the system Li_2O–SiO_2–CO_2. C. KRÖGER AND E. FINGAS. *Festschrift Tech. Hochschule*, pp. 296–306 (1935); abstracted in *Referat. Silikatliteratur*, **5** [1] 4896 (1938).—With the formation of metasilicate, an unstable equilibrium occurs from the effect of quartz on lithium carbonate. See "Action—," *Ceram. Abs.*, **14** [1] 21 (1935). M.V.C.

Formation of primary slags in blast furnaces. M. Y. OSTROUKHOV. *Metallurg*, **12** [3] 38–46 (1937); *Jour. Iron & Steel Inst.*, **137** [1] 310A (1938).—O. presents tabular data regarding the composition and melting points of eutectics with the lowest melting points in the binary and ternary systems containing silica with one or more of the following: alumina, lime, magnesia, and ferrous oxide in the presence of silicates of potassium, sodium, calcium, or manganese. It is suggested that the first slag formed by melting a synthetic mixture of oxides or silicates consists of the lowest melting point eutectic of the corresponding system. Such eutectics are not necessarily the most fluid melts; hence the really fluid slags which eventually appear may have a different composition from the first liquid phase formed. The analyses of the primary slags produced in different zones of the blast furnace, as determined by Bohn, Kinney, *et al.*, are discussed.

Hydrogen ion concentration measurements of clay slips. P. BREMOND. *Arts du Feu*, **1** [1] 30–31 (1938).—Modifications of the usual methods and a combined electrometric-colorimetric method are described. The relation between the viscosity and p_H of the slip is shown. F.E.V.

Improved method for determining thermal diffusivities. C. STARR. *Rev. Sci. Instruments*, **8**, 61–64 (1937).—The dynamic method of measuring thermal diffusivities devised by King has been improved. A sinusoidal temperature is impressed on one end of a wire specimen, and the thermal diffusivity is determined from the measured decrement of the temperature wave traveling along the specimen. Elimination or determination of heat losses is unnecessary. Greater precision is possible with this method than with previous methods. The thermal diffusivity of a pure specimen of nickel, measured at 25°C, was 0.15885 cm.²/sec., with a probable error of 0.06%. The thermal conductivity of nickel corresponding to this determination is 0.618 w./cm.°C. H.E.S.

Mineralogical composition and chemical action of slags produced in steelmaking. W. J. CROOK. Thesis, École Polytechnique Roi Carol II, Bucharest, 1936; *Jour. Iron & Steel Inst.*, **137** [1] 318A (1938).—C. discusses the present knowledge of the constitution of slags, the purpose of his investigations, the general role of slags, their classification on the basis of degrees of acidity, and the fundamental error of this system, methods and difficulties of investigating slags, the states of oxidation of iron in slags, influence of the presence of oxygen, the quaternary system SiO_2–FeO–Fe_2O_3–CaO, and the common features of all steelmaking processes. He also deals with the preparation of synthetic slags, their chemical analysis, microscopic examination, equilibria between the oxides of iron in slags, mineralogical composition of the slags investigated, the equilibrium diagram of the FeO–SiO_2–Fe_2O_3–CaO system, and chemical reactions taking place in this system as deduced from the diagram, studies of reactions occurring in the quasi-quaternary systems, the chemical action of slags in steelmaking, and an examination of different processes for the manufacture of steel.

Reaction mechanism of the formation and solution of aluminum and beryllium hydroxides. W. D. TREADWELL AND J. E. BONER. *Helv. Chim. Acta*, **17** [4] 774–87 (1934).—The authors attempt to obtain inside information on the secondary processes connected with the course of a hydroxide, from its primary formation to its separation as a precipitate, by measuring the turbidity and viscosity during the titration. E.W.S.

Simultaneous determination of calcium and magnesium by means of volumetric potentiometry. Application to the analysis of water. G. BERRAZ AND C. CHRISTEN. *Anales Soc. Cient. Argentina*, **120**, 103–107 (1935).—The authors found that the addition of a mixture of Na_2CO_3 and NaOH $N/10$ in excess to a dilute solution containing salts of Ca and Mg determines quantitatively the amounts of Ca and Mg present, provided the solution is neutral, is free from CO_2, and does not contain Ba and Sr or any heavy metal. The testing method is described, and results are given in tables. The investigation of this quick method is continued for application to rocks, ashes, plants, earths, etc. E.W.S.

Study on the celite part: III, System $3CaO \cdot Al_2O_3$–$2CaO \cdot Fe_2O_3$. TOSHIYOSHI YAMAUCHI. *Jour. Japan. Ceram. Assn.*, **45** [535] 433–46 (1937).—Microstructures and X-ray analyses of samples prepared by heating 12 mixtures of tricalcium aluminate ($3CaO \cdot Al_2O_3$) and dicalcium ferrite ($2CaO \cdot Fe_2O_3$) at 1370° and 1390°C were examined and compared with those of two samples made by firing $4CaCO_3 + Al_2O_3 + Fe_2O_3$ and $5CaCO_3 + Al_2O_3 + Fe_2O_3$, with the following results: (1) $2CaO \cdot Fe_2O_3$ and $3CaO \cdot Al_2O_3$ make each other solid solutions of limited miscibility. (2) Up to about 0.25 mole of $3CaO \cdot Al_2O_3$ is miscible with one mole of $2CaO \cdot Fe_2O_3$, forming a continuous series of solid solutions. Their X-ray diffraction patterns are of the $2CaO \cdot Fe_2O_3$ type. (3) Small amounts of $2CaO \cdot Fe_2O_3$ are miscible with $3CaO \cdot Al_2O_3$ and form a continuous series of solid solutions with diffraction patterns of the $3CaO \cdot Al_2O_3$ type. (4) In those samples con-

taining 0.26 to 1.5 moles of $3CaO \cdot Al_2O_3$ to 1 mole of $2CaO \cdot Fe_2O_3$, $3CaO \cdot Al_2O_3$ dissociates into free lime and probably $5CaO \cdot 3Al_2O_3$, and a series of solid solutions of the system $CaO–Al_2O_3–Fe_2O_3$ is formed. Their diffraction patterns are of the $2CaO \cdot Fe_2O_3$ type. When $3CaO \cdot Al_2O_3$ is as rich as 1.5 moles, however, diffraction lines of the $3CaO \cdot Al_2O_3$ type are also found. Thus each sample consists of a solid solution of the $2CaO \cdot Fe_2O_3$ type, free lime, and a solid solution of the $3CaO \cdot Al_2O_3$ type. (5) In samples containing more than 1.5 moles of $3CaO \cdot Al_2O_3$ to each 1 mole of $2CaO \cdot Fe_2O_3$, contents of free lime decrease gradually, the diffraction pattern of the $2CaO \cdot Fe_2O_3$ type disappears slowly, and diffraction lines of the $3CaO \cdot Al_2O_3$ type appear more clearly. (6) Spacing, *d*, of $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$ is almost the same as that of the sample consisting of 0.65 mole of $3CaO \cdot Al_2O_3$ and 0.35 mole of $2CaO \cdot Fe_2O_3$. (7) Spacing of $5CaO \cdot Al_2O_3 \cdot Fe_2O_3$ is almost the same as that of the sample consisting of 0.30 mole of $3CaO \cdot Al_2O_3$ and 0.70 mole of $2CaO \cdot Fe_2O_3$. **IV, System $5CaO \cdot 3Al_2O_3$–$2CaO \cdot Fe_2O_3$.** *Ibid.*, [537] 614–31.—Sixteen mixtures of pure pentacalcium trialuminate, $5CaO \cdot 3Al_2O_3$, and dicalcium ferrite, $2CaO \cdot Fe_2O_3$, were heated at 1300° and 1350°C or melted at higher temperatures. After cooling quickly or slowly, they were examined for microstructure and X-ray diffraction with the following results: (1) The two compounds form with each other solid solutions of limited miscibility. (2) The miscibility increases with rising temperature. (3) Samples composed of 0.10 to 0.35 mole $5CaO \cdot 3Al_2O_3$ and 0.90 to 0.65 mole $2CaO \cdot Fe_2O_3$ and fired at 1350°C and those containing 0.10 to 0.28 mole $5CaO \cdot 3Al_2O_3$ and fired at 1300° belong to the same solid solution series, and their X-ray diffraction patterns are similar to those of $2CaO \cdot Fe_2O_3$. Therefore a certain amount of $5CaO \cdot 3Al_2O_3$ seems to dissolve in the lattice of $2CaO \cdot Fe_2O_3$, the limited miscibility being 0.5 mole of $5CaO \cdot 3Al_2O_3$ per mole of $2CaO \cdot Fe_2O_3$. On the other hand, small amounts of $2CaO \cdot Fe_2O_3$ dissolve in $5CaO \cdot 3Al_2O_3$ and form solid solutions having diffraction patterns of the $5CaO \cdot 3Al_2O_3$ type. (4) In samples consisting of 0.60 to 0.10 mole $2CaO \cdot Fe_2O_3$ and 0.40 to 0.90 mole $5CaO \cdot 3Al_2O_3$, solid solution of the $2CaO \cdot Fe_2O_3$ type and that of the $5CaO \cdot 3Al_2O_3$ type coexist. (5) These solid solutions seem to have a eutectic point. (6) Lattice spacing of samples having the greatest miscibility in $2CaO \cdot Fe_2O_3$ is equal to that of the sample composed of 1 mole $2CaO \cdot Fe_2O_3$ and 0.25 mole $3CaO \cdot Al_2O_3$ reported in Part III and also to that of the fired sample of $5CaO + Al_2O_3 + Fe_2O_3$ but never reaches that of the fired sample of $4CaO + Al_2O_3 + Fe_2O_3$. **V, System $3CaO \cdot Al_2O_3$–$5CaO \cdot 3Al_2O_3$–$2CaO \cdot Fe_2O_3$.** *Ibid.*, [540] 880–96.—Y. studied the limited miscibility of the solid solutions in the systems $3CaO \cdot Al_2O_3$–$2CaO \cdot Fe_2O_3$, $5CaO \cdot 3Al_2O_3$–$2CaO \cdot Fe_2O_3$, and $3CaO \cdot Al_2O_3$–$5CaO \cdot 3Al_2O_3$–$2CaO \cdot Fe_2O_3$ with the following results: (1) In the system $3CaO \cdot Al_2O_3$–$2CaO \cdot Fe_2O_3$, microscopic observations and the determination of free lime indicate that the maximum miscibility of $3CaO \cdot Al_2O_3$ is about 0.05 mole to 1 mole of $2CaO \cdot Fe_2O_3$. (2) In the binary system $5CaO \cdot 3Al_2O_3$–$2CaO \cdot Fe_2O_3$, the maximum miscibility of $5CaO \cdot 3Al_2O_3$ is 0.4 mole to each mole of $2CaO \cdot Fe_2O_3$. (3) In the ternary system, there is a region where all fired samples give X-ray diffraction patterns of the $2CaO \cdot Fe_2O_3$ type and therefore compose a series of solid solutions with a lattice structure of the same type. The composition of the solid solution of the maximum miscibility in this region is about $6.2CaO \cdot 2.2Al_2O_3 \cdot Fe_2O_3$ or the ratio $3CaO \cdot Al_2O_3 : 5CaO \cdot 3Al_2O_3 : 2CaO \cdot Fe_2O_3 = 2:3:5$. (4) The region of solid solutions forms a swelled straight line connecting $6.2CaO \cdot 2.2Al_2O_3 \cdot Fe_2O_3$ and $2CaO \cdot Fe_2O_3$ in the ternary diagram of $CaO–Al_2O_3–Fe_2O_3$. Brownmillerite ($4CaO \cdot Al_2O_3 \cdot Fe_2O_3$) is a solid solution on the line. (5) The composition of a solid solution in the system $CaO–Al_2O_3–Fe_2O_3$ is fixed by the iron modulus or Al_2O_3/Fe_2O_3, provided there is sufficient lime. For Parts I–II see *Ceram. Abs.*, **17** [4] 163 (1938). S.K.

Temperature of formation of globules of primary blast-furnace slags. M. Y. Ostroukhov. *Metallurg*, **12** [4] 80–90 (1937); *Jour. Iron & Steel Inst.*, **137** [1] 311A (1938).—The downward movement of slags in blast furnaces is determined not only by the relative viscosity of different types of slag but also by their capacity to form globules and detach themselves from the surface of the ore. O. discusses the results of a detailed investigation in which the temperatures at which a number of salts (including alkaline and alkaline-earth chlorides) form droplets were determined in order to test the efficacy of the experimental technique adopted (these results are compared with data derived by other investigators); the temperatures of droplet formation of silica-alumina-lime, silica-lime-ferric oxide, and silica-ferric oxide mixtures as well as a number of blast-furnace slags were also determined. Drops are formed in the first ternary system mentioned at 1395°C by a mixture of a composition approximately that of the 1265°C eutectic, but mixtures with a composition approximately that of the lowest eutectic (1170°C) form globules only above 1450°C; hence slags of this composition can detach themselves from the ore only by changing their composition and attaining a fluid state. The addition of 5% of magnesia or of a small quantity of ferric oxide decreases the temperature of drop formation. Actual slags investigated behaved analogously to the quaternary system silica–alumina–lime–magnesia.

What's ahead in physics. K. T. Compton. *Rev. Sci. Instruments*, **8**, 43–47 (1937).—During the past third of a century, the discoveries of the electron, the X-ray, and radioactivity have brought about the greatest advances ever made in fundamental knowledge of the physical world and in practical applications of this knowledge to human welfare. These developments will undoubtedly continue. Fields of knowledge disclosed through exploration of the atomic nucleus may bring about a new set of developments of corresponding importance. H.E.S.

X-ray tube for the analysis of crystal structure. J. E. De Graaf and W. J. Oosterkamp. *Phillips Tech. Rev.*, **3** [9] 259–66 (1938).—The following special requirements must be made of an X-ray tube which is intended for the analysis of crystal structure: (1) the exposure time required must be short, (2) the radiation must be spectrally pure, and (3) the operation of the tube must be easy. A tube with a water-cooled anode which satisfies these requirements is described. Special attention is paid to the shape of focus necessary to obtain the greatest possible brightness. This tube is made especially for work outlined previously ("Examination—," *Ceram. Abs.*, **17** [11] 360 (1938)). H.K.R.

BOOK

Treatise on Quantitative Inorganic Analysis (with Special Reference to the Analysis of Clays, Silicates, and Related Minerals). J. W. Mellor and H. V. Thompson. Charles Griffin, London, 1938. 2d ed., revised. 774 pp. and index. Price 42s. Reviewed in *Chem. Trade Jour.*, **103**, 348 (1938).—While compiled mainly for the ceramic industries, this work deals fully with inorganic analysis in general. Of the five sections, one deals with methods of silicate analysis based on those of W. F. Hillebrand of the U. S. Geological Survey. The analysis of glasses, glazes, colors, and complex silicates forms another section. The revision shows evidence of thoroughness, particularly in regard to the new reagents and quicker methods of analysis now available. L.R.B.

PATENTS

Lead chromate pigments and process for producing. S. C. Horning (E. I. du Pont de Nemours & Co.). U. S. 2,139,753, Dec. 13, 1938 (Feb. 20, 1937). In a process for producing a pigment comprising lead chromate, the step of adding to a suspension of precipitated lead chromate for reaction therewith a small amount of a reducing agent comprising a water-soluble inorganic salt from the group consisting of a metal sulfide, stannous halide, and stannous sulfate, the amount of agent so employed being sufficient to restrain the crystal growth of the lead chromate.

Manufacturing crystalline substances. J. J. DIEKMANN (N. V. Chemische Fabriek "Gembo"). U. S. 2,142,265, Jan. 3, 1939 (Aug. 7, 1935). A method of producing crystalline sodium silicate comprises adding a hot sodium silicate solution at an initial temperature above crystallization temperature, which solution does not crystallize at the initial temperature but is supersaturated at crystallization temperature, to a sodium hydroxide solution at crystallization temperature, and maintaining the crystallization temperature in the mixture of sodium hydroxide solution and sodium silicate solution substantially constant, the relative proportions of sodium silicate solution and sodium hydroxide solution being such that the mixture is supersaturated with respect to the sodium silicate.

Pigment. EKBERT LEDERLE, MAX GÜNTHER, AND RUDOLF BRILL. U. S. 2,140,236, Dec. 13, 1938 (May 15, 1937). A process for the preparation of pigmentary metallic titanates comprises preparing a uniform and intimate mixture of "reactive metal compounds" and "reactive titanium compounds" by mutual precipitation from aqueous media, heating the mixture so obtained at a temperature within the range of about 500° to 800°C until titanate formation is substantially complete, and then heating the titanate at a higher temperature within the range of about 800° to 1100°C until the heated products exhibit sharp interference lines on an X-ray photograph.

Pigmentary lead titanate and method for making. HELMUT ESPENSCHIED (National Lead Co.). U. S. 2,140,222, Dec. 13, 1938 (Feb. 23, 1937). A process for the preparation of a pigment comprises mixing, until a uniform and intimate, very finely divided mixture is obtained, pigment-forming materials containing a "reactive lead compound" and a "reactive titanium compound," the amount of the "reactive lead compound" being not more than one mole PbO for every mole TiO_2, then heating the mixture at a temperature sufficient to form lead titanate but not sufficient appreciably to develop crystalline properties until formation of lead titanate is substantially complete, and thereafter heating at a higher temperature to develop crystalline properties.

Producing lead glazes. HERMANN HARKORT (Hans-Joachim Harkort). U. S. 2,140,381, Dec. 13, 1938 (April 10, 1933). A method of producing lead-containing glazes consists in fine-grinding metallic lead under the admission of air, thereby producing a mixture consisting only of the lead in various degrees of oxidation within the range from metallic lead to lead superoxide, mixing this mixture with the other constituents usual in lead glazes, and melting the mixture.

Production of sodium dichromate. M. J. UDY. Fr. 831,973, Jan. 12, 1938; *Chem.-Ztg.*, **62** [91] 826 (1938). D.A.B.

Production of zinc white (ZnO). L. GUTLOHN. Fr. 832,535, May 14, 1937; *Chem.-Ztg.*, **62** [89] 806 (1938). D.A.B.

Purifying aluminous materials. M. E. NORDBERG (Corning Glass Works). U. S. 2,141,444, Dec. 27, 1938 (March 16, 1937). The method of removing iron from high alumina materials includes mixing with a small quantity of the material from one to 10 times the amount of carbon necessary to satisfy the equation $Fe_2O_3 + 3C + 3Cl_2 = 2FeCl_3 + 3CO$, based on the initial iron content of a total batch of the material to be treated, placing the carbonaceous mixture adjacent the noncarbonaceous batch, heating the whole to a temperature of 900° to 1150°C while excluding air, and introducing chlorine gas so as to pass first through the carbonaceous mixture.

Titanium dioxide pigments. K. W. PETERSEN (I. G. Farbenindustrie A.-G.). U. S. 2,144,577, Jan. 17, 1939 (July 26, 1935). A process for the manufacture of improved white titanium dioxide pigments comprises precipitating on a white titanium dioxide pigment a metallic fluoride which is difficultly soluble in water in an amount between 2 and 50% by weight of the titanium pigment.

Treating siliceous materials. R. C. FOLGER (Cowles Detergent Co.). U. S. 2,141,132, Dec. 20, 1938 (June 11, 1936). In the process of treating aluminous siliceous material containing a substantial proportion of silica by the process steps of mixing and sintering the material with an alkali earth metal compound and an alkali metal compound to form alkali earth metal silicates and alkali metal aluminate, dissolving out the alkali metal aluminate from the sinter, and recovering the alumina and alkali metal compound from the alkali aluminate solution, the improvement comprises treating the residue with carbon dioxide to form hydrated silica and a bicarbonate of the alkali earth metal, separating the hydrated silica and the alkali earth metal bicarbonate, converting the bicarbonate to form an alkali earth metal carbonate, and utilizing the alkali earth metal carbonate thus obtained in forming additional charges for the sintering.

White pigment. EKBERT LEDERLE, MAX GÜNTHER, AND RUDOLF BRILL. U. S. 2,139,686, Dec. 13, 1938 (May 15, 1937). A composition adapted for use as a white pigment comprises crystalline zinc-magnesium titanate.

White pigment. EKBERT LEDERLE, MAX GÜNTHER, AND RUDOLF BRILL. U. S. 2,140,235, Dec. 13, 1938 (March 14, 1935). A process of preparing a white pigment comprises calcining at a temperature between about 500° and 800°C a mixture of a reactive zinc compound and titanium dioxide in the proportion of between 0.9 and 2 moles of reactive zinc compound to 1 mole of titanium dioxide for such a time that the titanium dioxide is practically completely bound to the zinc and thereafter heating the resulting product at a higher temperature not exceeding about 1100°C until it exhibits sharp interference lines on an X-ray photograph.

Zirconium carboxide and method of making. C. J. KINZIE AND D. S. HAKE (Titanium Alloy Mfg. Co.). U. S. 2,143,013, Jan. 10, 1939 (Aug. 7, 1935).

General

Cement and gypsum dusts as protectors. LEROY U. GARDNER. *Concrete, Cement Mill Ed.*, **46**, 189–90 (1938).—It was found that men exposed to a gypsum dust mixed with apparently hazardous amounts of silica dust did not get silicosis. Other field studies in the iron ore and cement industries showed similar effects. Animal experiments have shown gypsum, hematite, calcium fluoride, and metallic aluminum dusts and the silicates in granite to be protective. The silica hazard, therefore, is not defined solely by the silica particles in the atmosphere. Other components modify the action. Protector dusts should not be used to combat silicosis, as the knowledge is inaccurate and too much of any dust is a nuisance. Gypsum dust seems to coagulate silica dust in the air and prevent it from reaching the lungs. Other dusts exert their effect in the body. More experimentation is needed. W.D.F.

Critical study of differential thermal method for identification of clay minerals. F. H. NORTON. *Jour. Amer. Ceram. Soc.*, **22** [2] 54–63 (1939).

Economic effects of accident prevention and occupational-disease control in the chemical industry. R. C. STRATTON. *Trans. Amer. Inst. Chem. Engrs.*, **33**, 95–105 (1937).—The elimination of physical hazards, the revision of mechanical processes, sanitary surroundings, recognition and knowledge of occupational exposures, and proper medical advice, combined with engineering initiative and supervision of a high order, will prevent accidents and lessen occupational diseases. H.E.S.

History and general discussion on ceramics. P. HENRY. *Ceram. Forum*, **5** [12] 2, 6 (1938). H.E.S.

Importance of research and development in maintaining technical progress. M. W. SMITH. *Eng. Jour.*, **21** [11] 508 (1938).—Research is one of the most effective means

of protecting capital invested in industry from the decay of obsolescence. Mortality is highest with companies which carry on little or no research. Research may be divided into the following groups: basic, fundamental, specific, and commercial development. The establishing of fellowships in universities is sometimes employed by corporations as a means of doing a portion of their fundamental research. The recipients of the fellowships may or may not enter the employ of the corporation at the termination of the fellowship, which usually lasts 1 to 2 years. B.C.R.

Laboratory of calorimetry of the Office Central de Chauffe Rationnelle, Paris. ANON. *Nature* [Paris], No. 3034, pp. 214–15 (1938).—The laboratory is described. R.W.D.

Planning pottery factories. F. G. YORATH. *Trans. Ceram. Soc.*, **37** [9] 404–25 (1938).—Although Y. refers to all ceramic plants in general, he deals particularly with general earthenware and chinaware plants. The location and layout of such plants are discussed from the viewpoint of an experienced architect. R.A.H.

Progress in dust protection. HEINZ EISENBARTH. *Gasmaske*, **10**, 35–38 (1938).—Gravimetric tests on early types of dust respirators showed that they caught 90% of the dust, and this was thought to give sufficient protection. Later it was found that these caught not more than 50% of the dust less than 3 μ in size. The amount of dust passing a filter is now determined by optical methods or by counting and size measurement. Six years ago the first Auer filter for stopping fine dusts was manufactured. A new dust filter, the Kollix, consists of a number of annular rings of filtering material put together like a closed accordion. This filter fits tightly against a rubber gasket in a light metal case from which it can be removed by a key. The case screws into a full or half facepiece. A bag is drawn over the case to act as a prefilter. This respirator allows a flow of air at 30 liters/min. at only 6 to 7 mm. water pressure, and the case and filter weigh only 95 g. A new facepiece of rubber has also been developed which has a mica exhalation valve and a self-working perspiration separator. W.D.F.

So-called physical allergy as a compensable occupational disease. F. LUCE. *Arch. Gewerbepath. & Gewerbehyg.*, **8**, 206–22 (1938).—A ceramic worker, a woman 45 years old, of previous sound health developed a peculiar skin disease after becoming a dental assistant in the manufacture of artificial teeth. This work involved continuous attention to the firing of the porcelain product in an oven which was in a poor, as well as a dangerous, condition. The firebrick casing of the oven, only 10 cm. thick, had become defective; the temperature gage was not working, and heat intended to be kept below 1300° or 1400° often rose to 1900°. When opening the turret door, the woman was supposed to be at least 25 or 30 cm. distant from the oven heat, but she was frequently much nearer, the automatic protections or guides not working. From the wire network of rods of silicon carbide, often lacking 35 or 40 pieces, disintegrating dust clouds often rushed out when the oven door was opened; her eyes were somewhat protected by dark-blue spectacles. Reddening and swelling of the skin of her face, neck, upper body, and upper arm were the earlier symptoms; later, itching and inability to endure water, alcohol, or anything on her skin made her miserable. The pores of her face, especially of the cheeks, became enlarged. Eventually other symptoms, *e.g.*, tremor of the hands, dizziness, extreme nervousness, sleeplessness, and emaciation, were added. She seems not to have thought of "laying off" such a job until frightened by her condition when far advanced. Between 1931 and 1935 various doctors of the health insurance associations examined her from time to time, and she was usually estimated as a 100% victim of an occupational disease, but for some reason she was never qualified as coming under the several specifications for skin diseases which the advancing ordinances steadily broadened to recognize. At a Berlin clinic she was adjudged to have a "physical allergy" to heat, as others have to cold or mechanical physical effects. The term, relatively new, was applied first by Duke in 1925. L. reviews thoroughly all available literature, citing 47 authors. He discusses the case for its clinical, etiological, and pathogenic features, its therapy (largely useless), and its frequency (much greater than might be supposed), not so much for its causes by exposure to terrific heat as for its place in the physical allergies. He fails to mention what became of the unfortunate patient and whether some adjudicator finally allowed her the evidently deserved pension. K.R.

BOOKS AND SEPARATE PUBLICATIONS

Laboratories that make fire assays, analyses, and tests on ores, minerals, and other inorganic substances. C. W. DAVIS AND M. W. VON BERNEWITZ. *U. S. Bur. Mines Information Circ.*, No. 6999R, 27 pp. Free. Revision of *ibid.*, No. 6999 (*Ceram. Abs.*, **17** [8] 294 (1938)). R.A.H.

Rise of Midland Industries. W. H. B. COURT. Oxford University Press. C. presents a brief history of the use of fire clay in the Stourbridge district of England and a fuller history of the manufacture of glass in the Birmingham and Stourbridge districts. A.B.SEARLE

NEW JOURNAL

Les Arts du Feu. Céramique, Verrerie, Vitraux, Émaux. Published monthly by Les Éditions de l'Art Vivant, 116bis, Champs-Élysées, Paris. Vol. 1, No. 1, May, 1938. Price 100 fr., foreign 130 fr. per year. This is the official organ of the Association Scientifique et Technique de Céramique and the Fédération Nationale de la Céramique et de la Verrerie. The scope is very wide, including scientific development, use of ceramic materials in architecture and decoration, building policy, and artistic viewpoint. The first issue is fully illustrated. F.E.V.

PATENTS

Colored glass-coated refractory granules. C. E. HILLERS AND H. L. SMALL (Blue Ridge Slate Corp.). U. S. 2,139,955, Dec. 13, 1938 (March 17, 1937). Refractory mineral roofing granules have a nonblooming, colored coating consisting of the fusion product of aqueous sodium silicate solution, a dry insoluble form of lead, dry finely ground barium carbonate, dry powdered borax, and a coloring agent.

Manufacture of ceramic material. BRITISH THOMSON-HOUSTON CO., LTD. Brit. 497,140, Dec. 30, 1938 (June 28, 1937).

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Jour. Hyg.
Jour. Inst. Sanitary Engrs.
Jour. Phys. & Radium
Jour. Soc. Chem. Ind. Japan
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Koks & Khim.
Kolloid-Zhur.
Legkie Metally
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Mem. Phys. Ukrain.
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Metall & Erz
Metallurg
Métallurgie
Metallwaren-Ind. & Galvano-Tech.
Metaux & Corrosion
Mikrochim. Acta
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Mitt. Opt. Inst. Tech. Hochschule Berlin
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Vsesoyuz. Nauch.-Issled. Inst. Tsementov
Wärme
Wärme- & Kälte-Tech.
Werkstattstechnik
Wire & Wire Prod.
Zapiski Vserossiĭskogo Mineral. Obshchestva
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Vol. 22, No. 3, Journal, pp. 65-96 THE JOURNAL and CERAMIC ABSTRACTS, MARCH, 1939 [illegible] Ceramic Abstracts, pp. 65-96